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Ministry of Transportation
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Aggregate and Soil Proficiency Sample Testing Program for 2008

MERO-032

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Abstract	The Materials Engineering and Research Office, Soils and Aggregates Section, conducts a proficiency sample-testing program each year to provide a means for participating laboratories to see if they are performing satisfactorily. We also conduct a sample testing program for the tests related to Superpave consensus properties of aggregates. This is conducted along with our annual Aggregate and Soil Proficiency Sample Testing Program. The laboratories are asked to perform a number of different tests on pairs of samples that have been prepared and randomly selected at the MTO Laboratory. The samples are delivered to the participating laboratories starting in June, and they report their results for the aggregate and soil proficiency sample tests starting in the early part of August. A preliminary report issued in mid-September allows the laboratories to examine their procedures or equipment and correct any problems that may have occurred. This is the final report for both the Aggregate and Soil Proficiency Samples and Superpave Consensus Property Testing for 2008. This year, two hundred and fifteen laboratories from the private and public sector participated in the Aggregate and Soil Proficiency Sample Testing Program. Fifty-nine laboratories from the private sector and MTO Downsview laboratory reported results for the Superpave consensus property tests. Results of the 2008 Aggregate and Soil Proficiency Sample Testing Program are found to be consistent with the results reported in the last three years, but, in some of the tests, the variations show noticeable improvements compared to previous years' results. Although there is improvement in results, strong laboratory biases still remain in many of the test procedures. The variations in the results for the Superpave Consensus Property Testing Program are found to be consistent with the values published in ASTM precision statements.
Key Words	Aggregate, consensus property, correlation, laboratory, proficiency testing, soil, Superpave
Distribution	Unrestricted technical audience.

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Executive Summary

The Soils and Aggregates Section of the Materials Engineering and Research Office runs an annual proficiency sample testing program for aggregate and soil tests. This program provides a means for participating laboratories to see if they are performing satisfactorily. The laboratories are asked to perform a number of different tests on pairs of samples that have been prepared and randomly selected by the MTO Soils and Aggregates Laboratory. The samples are delivered to the participating laboratories starting in June. The laboratories report their results in the first week of August. A preliminary report issued in mid-September gives feedback to the participants while they are still operational in the current year. This allows them to examine their procedures or equipment and correct any problems that may have occurred. A final report is issued after analysis of the data has been completed.

This is the final report for the 2008 MTO Aggregate and Soil Proficiency Sample Testing and the Superpave Aggregate Consensus Property Testing Programs. This year, two hundred and fifteen laboratories from the private and public sector participated in the Aggregate and Soil Proficiency Sample Testing Program. Of these, one hundred and fifty-two were aggregate producers' and road builders' Quality Control (QC) laboratories. The remainder were engineering testing consultants and owners' laboratories. Participation in this program is required by the contract documents if the contractor's QC process is to be acceptable to MTO. In general, these contractor and supplier laboratories are conducting particle size analysis, wash pass 75 μm, percent crushed particles, percent asphalt coated particles, and density tests for granular base and sub-base aggregates.

Sixty laboratories reported results for the Superpave Aggregate Consensus Property Testing Program in 2008. The laboratories that participate in this program conduct uncompacted void content of fine aggregate, sand equivalent value of fine aggregate, percent of fractured particles in coarse aggregate, and flat particles, elongated particles, or flat and elongated particles in coarse aggregate tests, in accordance with the ASTM/AASHTO test methods.

Reports to individual laboratories contain ratings for each test method, which are based on the standardized deviate for that test (i.e. a rating of 5 for data within 1.0 standard deviation of the mean, a rating of 0 for data 3.0 or more standard deviations from the mean). Ratings of each test method are also used to calculate an overall laboratory rating for each category of tests. This rating system has acted as an incentive for laboratories to improve their performance. The rating is also used as a guide by MTO to select laboratories for its quality assurance testing and for qualifying referee laboratories.

Results of the 2008 Aggregate and Soil Proficiency Sample Testing Program are found to be consistent with the results from previous years and, in some of these tests, the results show improvements compared to previous years' results and precision estimates published by AASHTO, MTO, or ASTM. Particularly, sieve analysis of coarse aggregate, percent crushed particles of coarse aggregate, relative density and absorption of coarse and fine aggregates, and micro-Deval abrasion (fine) show improvements over the precision estimates published

by ASTM or MTO. Although the precision of most of the test methods compares favourably in relation to the results of previous studies and the precision estimates where available, strong laboratory biases still remain in some of the test methods. The variations in soil test results are consistent with the values reported in the previous three years of study, but the scatter plots show a strong laboratory bias.

Most of the laboratories who participated in the 2008 Superpave aggregate tests have been participating in this program for the past six years. They have now gained experience with these test procedures. The variations of two of the Superpave tests in 2008 are lower than that of the values published in ASTM precision statements. However, the scatter diagrams for the Superpave tests, with the exception of uncompacted void content, show strong laboratory biases.

The Soils and Aggregates Section continues to carry out the inspection of laboratories providing soil testing services to the ministry. This inspection is being done at the request of laboratories. The laboratories that are inspected and accepted by MTO must request a re-inspection whenever technicians or equipment change. To date, thirty-eight laboratories have been inspected, of which thirty-four laboratories have been approved to do testing of soils for MTO work.

1. Introduction

This is the final report of the 2008 interlaboratory testing program organized by MTO for aggregate and soil test methods. It is primarily intended to provide a means for laboratories used by MTO to see if they are performing satisfactorily and to qualify these laboratories to perform quality control and quality assurance testing for MTO contracts[1]. The design of the testing program is based on procedures for determining the precision and variability of test methods. Interested readers should refer to ASTM C670[2], C802[3], E177[4], and E178[5] for further information on interlaboratory testing programs.

A total of two hundred and fifteen laboratories participated in the Aggregate and Soil Proficiency Sample Testing Program conducted in the summer of 2008. The participants were also asked to submit results for Superpave aggregate consensus property tests, if they were equipped to perform those tests. Fifty-six laboratories submitted results for all of the tests related to the consensus properties. Participants in both testing programs included the MTO laboratory, the remainder being from the private sector (contractors, aggregate producers, and engineering consultants) and municipalities. Samples were delivered to laboratories in early June. A preliminary report was issued to the participants in mid-September.

Reports to individual laboratories contain ratings for each test method, which are based on the standardized deviate for that test (i.e. a rating of 5 for data within 1.0 standard deviation of the mean, a rating of 0 for data 3.0 or more standard deviations from the mean). Ratings of each test method are also used to calculate an overall laboratory rating. This rating system has acted as an incentive for laboratories to improve their performance.

The computer program that was developed by MTO to handle the computation and presentation of test data has two statistical methods, namely the Critical Value Method and the Iterative (Jackknife) Technique, to detect outlying observations or outliers in a set of data. For details of the program, refer to the User's Manual (report MERO-013) by Vasavithasan and Rutter, 2004. A number of statistical methods are available to test the hypothesis that the suspect observations are not outliers, but the MTO study follows the Critical Value Method recommended in Section 4 of ASTM E178. The critical value method and iterative techniques are based on two different statistical approaches. As a result, the confidence intervals yielded by these two methods differ widely depending on the number of observations (number of laboratories participating in a particular test method) and the distribution of data.

1 Laboratories must also be inspected and recognized by the Canadian Council of Independent Laboratories (CCIL).
2 ASTM C670 Practice for Preparing Precision and Bias Statements for Test Methods of Construction Materials.
3 ASTM C802 Practice for Conducting an Inter-laboratory Test Program to Determine the Precision of Test Methods of Construction Materials.
4 ASTM E177 Practice for Use of Terms Precision and Bias in ASTM Test Methods.
5 ASTM E178 Practice for Dealing with Outlying Observations.

The critical value used in this study is that value of the sample criterion, which would be exceeded by chance with some specified probability (significance level) on the assumption that all observations in the sample come from the same normally distributed population. The critical values provided in ASTM E178, Table 1 are limited to 147 observations, but over 200 laboratories participate in our annual testing program. The critical values that are being used for the MTO study were calculated at five percent significance level (Grubbs' test) based on Grubbs' (1969 and 1972) recommendations for identifying outliers. The jackknife method recommended by Manchester (1979) is used where the strict application of the critical value method tends to include results that may not stand the best chance of representing the testing performed in conformance with each of the test methods.

2. Test Results

2.1 TABLE OF TEST RESULTS

Each participant receives an individual summary of results for their laboratory. An example of a typical report is shown in Tables 1, 2, 3, and 4. Each Table of Results identifies the laboratory by number and compares the laboratory's data with the means obtained after statistical analysis of the data received from all laboratories. The identity of the laboratories is kept confidential.

Column 1 gives the test method as designated in the MTO Laboratory Testing Manual.

Columns 2 and 3 show the test data submitted by the laboratory for a pair of samples.

Columns 4 and 5 show the mean (average) test value for each sample, for all laboratories performing the test, after removal of outliers and/or invalid test data.

Columns 6 and 7 list the standardized deviate for each test result. The standardized deviate is used to show how the individual test results compare to the mean. It is obtained by subtracting the mean of all data ($\overline{X}$) from the actual test result reported by the laboratory (X_i) and dividing by the standard deviation (s). That is:

$$\text{Standardized deviate} = \frac{\left(X_i - \overline{X}\right)}{s}$$

If the test result is less than the mean, the standardized deviate is negative and, if the test result is greater than the mean, the standardized deviate is positive. In brief, the standardized deviate tells us how many standard deviations the test result is away from the mean.

Columns 8 and 9 list the test method ratings, which are similar to the standardized deviate, but are in a simple numeric form. Ratings are determined as follows:

Rating 5 - data within 1.0 standard deviation of the mean.
Rating 4 - data within 1.5 standard deviations of the mean.
Rating 3 - data within 2.0 standard deviations of the mean.
Rating 2 - data within 2.5 standard deviations of the mean.
Rating 1 - data within 3.0 standard deviations of the mean.
Rating 0 - data 3.0 or more standard deviations from the mean or data considered to be outlying by other methods.

A negative sign simply indicates a result that is smaller than the mean. If one of the paired test results for a given test is excluded based on the outlier criteria, the other test result is still subjected to the statistical analysis and is only excluded if it also fails to meet the criteria.

An outlying observation is one that appears to deviate markedly from the sample population. It may be merely an extreme manifestation of the random variability inherent in the data, or may be the result of gross deviation from the prescribed experimental procedure, calculation errors, or errors in reporting data. The outlier criteria employed for exclusion of test results from the analysis will depend on the distribution of data and the number of participants in a test. The iterative technique is one of the methods employed in this study for the selection of outliers, and is used where the strict application of critical value method tends to include the data that does not belong to the population. In the critical value method, the standardized deviate of a lab result is compared with the critical value corresponding to the number of participants in that particular test for rejecting an outlier. The critical value is greater than 3 when the number of participants in a particular test method is 30 or more. For this reason, results with more than 3 standardized deviates may not have been identified as an outlier unless it is higher than the critical value, but a zero rating is nevertheless assigned for the test result in question. For example, if the computed standardized deviate for a lab result is 3.236 and the critical value corresponding to the number of participants in that particular test is 3.427, the lab will not be identified as an outlier but a zero rating will be assigned.

Significance need not necessarily be attached to a single low rating. However, a continuing tendency to get low ratings on several pairs of samples or on a series of tests from one procedure (e.g. sieve analysis) should lead a laboratory to re-examine its equipment and test procedure. A laboratory that reports data for a specific test consistently lower or higher than the mean over a number of test periods also needs to re-examine their test procedure, because this is evidence of a systematic bias in how the laboratory conducts the procedure. Any computer program that is used by a laboratory to calculate test results should be verified as part of this examination.

2.2 SCATTER DIAGRAMS

Youden scatter diagrams are supplied with this report (see Appendices D1 and D2). A laboratory can locate itself on the diagrams by plotting its test value for the first sample (1.08) on the horizontal axis, against its test value for the second sample (2.08) on the vertical axis. The horizontal and vertical axes are of equal length and are scaled to give the most informative display of the plotted points. In some cases, the outlying results plot outside the boundaries of the diagram. If the results from two or more laboratories happen to coincide, a single point is plotted.

Below each scatter diagram, the test number and title are given, followed by a table of statistical calculations for both samples. Here the mean, median, and standard deviation for each sample are given. The number of laboratories reporting valid data and the laboratories eliminated by statistical analysis are also listed.

The vertical and horizontal crosshairs on the plots represent the mean values for all the results on the first sample (1.08) and the second sample (2.08), respectively. These lines divide the diagram into four quadrants, numbered 1 through 4, beginning in the upper right-hand quadrant and continuing clockwise. In an ideal situation where only random errors occur, the points are expected to be equally numerous in all quadrants and will form a circular distribution. This follows because plus and minus errors should be equally likely.

Often, however, the points tend to concentrate in quadrants 1 and 3 on the diagram. This occurs because laboratories tend to get high or low results on both samples. This gives evidence of individual laboratory biases. As the tendency to laboratory bias increases, the departure from the expected circular distribution of points towards a linear distribution from quadrant 1 to 3 occurs. Such a distribution of points indicates systematic variation. Figure 1 gives examples of scatter diagrams.

Table 1. Summary of Results for Laboratory 47

TEST RESULTS FOR LABORATORY NUMBER 47 DATE PREPARED: November 3, 2008

COARSE AGGREGATE REFERENCE SAMPLES 1.08 & 2.08

TEST METHOD	LABORATORY DATA		MEAN OF LABORATORIES		STANDARDIZED DEVIATE		LAB RATING	
	1.08	2.08	1	2	1	2	1	2
LS-601 Wash Pass 75 μm (Coarse Agg.)	0.410	0.350	0.386	0.393	0.120	-0.214	5	-5
LS-602 – Coarse Aggregate								
Percent Passing 19.0 mm	98.100	98.000	97.867	97.793	0.453	0.372	5	5
Percent Passing 16.0 mm	91.400	90.600	91.083	90.722	0.365	-0.133	5	-5
Percent Passing 13.2 mm	83.300	81.800	82.913	82.277	0.344	-0.364	5	-5
Percent Passing 9.5 mm	70.200	68.400	69.022	68.092	0.972	0.214	5	5
Percent Passing 4.75 mm	52.250	50.410	51.153	50.181	0.919	0.158	5	5
LS-603 Los Angeles Abrasion, %	22.400	23.000	22.382	22.110	0.014	0.802	5	5
LS-607 Percent Crushed Particles	60.500	60.900	63.138	63.558	-0.693	-0.714	-5	-5
LS-608 % Flat & Elongated Particles	2.400	2.500	3.271	3.476	-0.548	-0.546	-5	-5
LS-609 Petrographic Number (Concrete)	107.40	107.70	114.8	116.5	-1.111	-1.062	-4	-4
LS-614 Freeze-Thaw Loss, %	7.600	7.000	7.620	7.676	-0.013	-0.404	-5	-5
LS-618 Micro-Deval Abrasion Loss (CA)	16.700	16.400	14.752	14.707	2.536	1.990	1	3
LS-620 Accelerated Mortar Bar (14 Days)								

Blank spaces represent not tested.
* - Calculation considered outlier

Table 2. Summary of Results for Laboratory 47

TEST RESULTS FOR LABORATORY NUMBER 47			DATE PREPARED: November 3, 2008					
FINE AGGREGATE REFERENCE SAMPLES 1.08 & 2.08								
TEST METHOD	LABORATORY DATA		MEAN OF LABORATORIES		STANDARDIZED DEVIATE		LAB RATING	
	1.08	2.08	1	2	1	2	1	2
LS-623								
Maximum Wet Density (g/cm^3)	2.311	2.339	2.320	2.317	-0.225	0.479	-5	5
Maximum Dry Density (g/cm^3)	2.140	2.170	2.151	2.151	-0.270	0.402	-5	5
Optimum Moisture, %	8.000	7.800	7.951	7.931	0.108	-0.331	5	-5
LS-604 – Coarse Aggregate								
Relative Density (O.D.)	2.674	2.664	2.657	2.657	2.437	0.903	2	5
Absorption	0.840	0.850	0.971	0.954	-1.472	-1.202	-4	-4
LS-621								
Asphalt Coated Particles, %	36.400	37.200	36.530	37.139	-0.022	0.010	-5	5

Blank spaces represent not tested.
* - Calculation considered outlier

Table 3. Summary of Results for Laboratory 47

TEST RESULTS FOR LABORATORY NUMBER 47 DATE PREPARED: November 3, 2008

FINE AGGREGATE REFERENCE SAMPLES 3.08 & 4.08

TEST METHOD	LABORATORY DATA		MEAN OF LABORATORIES		STANDARDIZED DEVIATE		LAB RATING	
	3.08	4.08	3	4	3	4	3	4
LS-605 – Fine Aggregate								
Relative Density (O.D.)	2.662	2.665	2.659	2.660	0.297	0.598	5	5
Absorption	0.624	0.644	0.644	0.642	-0.180	0.016	-5	5
LS-606 – Coarse Aggregate $MgSO_4$ Soundness Loss, %								
LS-606 – Fine Aggregate $MgSO_4$ Soundness Loss, %								
LS-619 – Fine Aggregate Micro-Deval Abrasion	11.900	11.400	11.868	11.798	0.037	-0.518	5	-5
LS-602 – Fine Aggregate								
Percent Passing 2.36 mm	41.900	40.300	40.950	40.401	0.566	-0.061	5	-5
Percent Passing 1.18 mm	34.400	33.600	33.307	32.890	0.604	0.396	5	5
Percent Passing 600 μm	27.200	27.000	26.466	26.290	0.443	0.434	5	5
Percent Passing 300 μm	19.000	18.900	18.374	18.235	0.566	0.592	5	5
Percent Passing 150 μm	12.500	12.300	12.025	11.962	0.689	0.474	5	5
Percent Passing 75 μm	8.670	8.470	8.230	8.222	0.862	0.462	5	5

Blank spaces represent not tested.
* - Calculation considered outlier

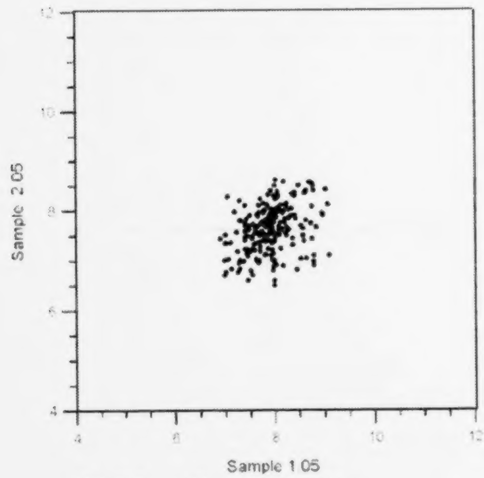
Table 4. Summary of Results for Laboratory 47

TEST RESULTS FOR LABORATORY NUMBER 47 DATE PREPARED: November 3, 2008

SOILS REFERENCE SAMPLES 1.08 & 2.08

TEST METHOD	LABORATORY DATA		MEAN OF LABORATORIES		STANDARDIZED DEVIATE		LAB RATING	
	1.08	2.08	1	2	1	2	1	2
LS-702 – Sieve Analysis of Soil								
Percent Passing 2.00 mm	100.00	100.00	99.997	99.996	-	-		
Percent Passing 425 μm	100.00	100.00	99.803	99.806	1.298	1.304	4	4
Percent Passing 75 μm	99.600	99.500	99.079	99.098	1.454	1.167	4	4
Percent Passing 20 μm	82.300	80.000	80.394	80.070	0.417	-0.015	5	-5
Percent Passing 5 μm	47.000	44.100	44.830	44.241	0.568	-0.047	5	-5
Percent Passing 2 μm	30.300	29.000	29.915	29.432	0.115	-0.135	5	-5
LS-703								
Liquid Limit, %	33.000	32.800	32.642	32.745	0.260	0.038	5	5
LS-704								
Plastic Limit, %	19.400	19.300	19.000	18.946	0.361	0.359	5	5
Plasticity Index, %	13.600	13.500	13.811	13.847	-0.114	-0.226	-5	-5
LS-705								
Specific Gravity of Soil	2.708	2.724	2.719	2.724	-0.379	-0.006	-5	-5
AGGREGATE CONSENSUS PROPERTIES								
Uncompacted Void Content	41.800	41.800	41.863	41.909	-0.110	-0.202	-5	-5
Sand Equivalent Value	32.800	32.800	35.539	35.236	-0.683	-0.616	-5	-5
Percent Fractured Particles	54.600	54.900	63.585	64.403	-2.283	-2.552	-2	-1
% Flat & Elongated Particles	0.300	0.300	0.482	0.560	-0.518	-0.825	-5	-5

Blank spaces represent not tested.
* - Calculation considered outlier

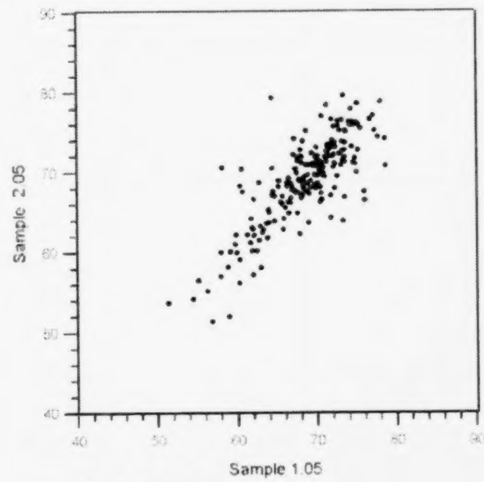


Test 25: Percent Passing the 75 um Sieve

	Mat 1	Mat 2
Mean	7.930	7.630
Median	7.800	7.600
Std Dev	0.460	0.470
n = 203		

Labs Eliminated: 447, 497, 452, 516

Scatter diagram for a test showing random variation with little laboratory bias

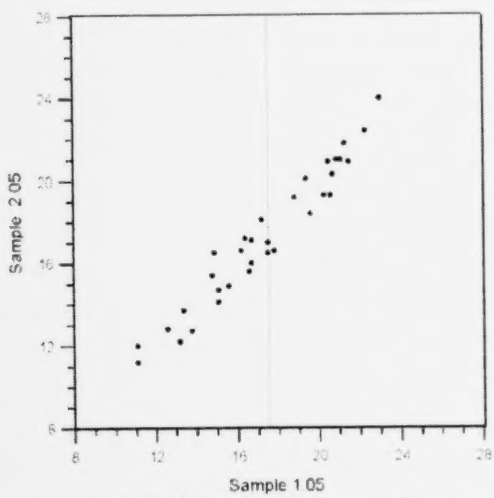


Test 12: Percent Crushed Particles

	Mat 1	Mat 2
Mean	68.491	66.905
Median	68.300	64.500
Std Dev	6.054	6.402
n = 201		

Labs Eliminated: 345, 350, 436, 490

Scatter diagram for a test showing a combination of random variation and laboratory bias for some laboratories

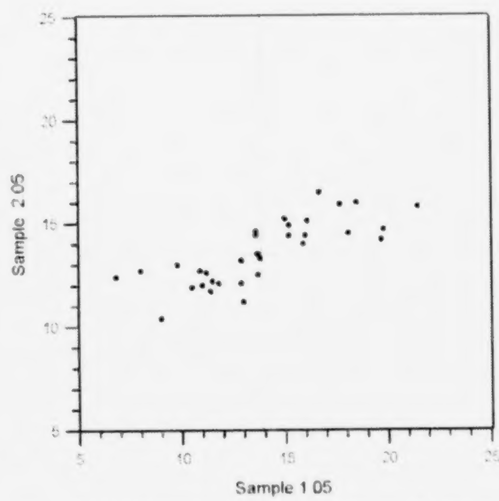


Test 29: MgSO4 Soundness (Fine Aggregate), % Loss

	Mat 1	Mat 2
Mean	17.370	17.258
Median	15.800	15.600
Std Dev	3.276	3.325
n = 32		

Lab Eliminated: None

Scatter diagram for a test showing pronounced between laboratory bias and equal variation for each material



Test 11: MgSO4 Soundness (Coarse Aggregate), % Loss

	Mat 1	Mat 2
Mean	13.600	13.570
Median	12.900	13.600
Std Dev	3.533	1.541
n = 31		

Lab Eliminated: None

Scatter diagram for a test with pronounced between laboratory bias but unequal variation for each material

Figure 1. Examples of Scatter Diagrams

2.3 OUTLIERS

In dealing with suspected outlying observations or 'outliers', our purpose is to remove those observations that do not belong to the sample population and to provide some statistical criteria for doing so. There are a number of ways to do this. In most of these, as ASTM E178 states, 'the doubtful observation is included in the calculation of the numerical criterion (or statistic), which is then compared with a critical value based on the theory of random sampling to determine whether the doubtful observation is to be retained or rejected.' The critical value is that value of the sample criterion that would be exceeded by chance with some specified (small) probability on the assumption that all observations did indeed constitute a random sample from a common system of causes, a single parent population, distribution, or universe.

The MTO study follows the criteria recommended for single samples in Section 4 of ASTM E178 for rejecting the doubtful observations at the ninety-five percent confidence level. The critical value method is based on the assumption of normality, and the critical values are calculated using Student's T distribution. The assumption in this method is that all of the observations come from the same normal population. The doubtful observation is included in the calculation of mean and standard deviation of the population. Then the critical value, T_n, for that observation, n, in question is calculated and compared with the critical value based on the theory of random sampling. The doubtful observation is rejected if T_n is higher than the critical value for the five percent significance level. The outlier is removed from the data set and the iterations are continued until no outliers are detected, and a revised mean and standard deviation are calculated after deleting the outlier. The ratings of the laboratories are determined based on the revised mean, standard deviation, and standardized deviate.

In some cases, the strict application of the critical value method tends to include laboratories in the population that are not doing a good job. In those cases, the application of the iterative technique (Manchester[6]) is used. The Constant C in the iterative technique is computed using Fisher's F distribution, and it depends on the number of participating laboratories in a particular test. In this technique, an outlying observation is rejected based on a statistical criterion, but the confidence interval may vary depending on the number of participants and the distribution of sample population.

In the iterative technique, after screening the test results for any errors, the doubtful test result is included in the calculation of mean and standard deviation of the data set. The absolute residual values (actual test result minus the mean) are then computed and test result farthest from the mean by a unit of Cs (standard deviation, s, multiplied by a constant C) is identified as an outlier. One outlier at a time is identified and rejected in a manner similar to that of critical value method.

6 The Development of an Interlaboratory Testing Program for Construction Aggregates, by L. Manchester, Ministry of Transportation, Ontario, Engineering Materials Office Report EM-33, Downsview, December, 1979.

3. Discussion

The following discussion contains general and test-specific comments for the 2008 test period. Where ASTM or AASHTO precision statements are published for a given test, an attempt has been made to compare these with the statistics for this period.

A discussion of statistical techniques is presented in the Glossary of Terms, found in Appendix A.

3.1 NOTES ON MATERIAL SOURCES

Materials used in this test period were as follows:

- Coarse and fine aggregate tests, including Sieve Analysis, Percent Crushed Particles, Petrographic Analysis (CA), Magnesium Sulphate Soundness (CA), Freeze-Thaw, Moisture Density Relationship, Relative Density and Absorption (FA), Micro-Deval Abrasion Loss (FA), Uncompacted Void Content, Sand Equivalent Value, and Percent Fractured Particles – Goodwood Pit Granular A from Lafarge Canada Inc. (MTO MAIDB No. N02-089).
- Coarse aggregate tests, including Wash Pass 75 μm, Percent Flat and Elongated Particles, Relative Density and Absorption (CA), Los Angeles Abrasion, Micro-Deval Abrasion Loss (CA), and Percent Flat, Elongated, or Flat and Elongated Particles – Caledon Outwash from Caledon Sand and Gravel Inc. (MTO MAIDB No. O10-111).
- Fine Aggregate Petrographic Examination – Beach sand from Erie Sand & Gravel, Leamington Pit (MTO MAIDB No. E02-020).
- Soil tests – Lake St. Clair Clay Plain clay from Dresden, Chatham (MTO MAIDB No. W02-027).

3.2 NOTES ON SAMPLE PREPARATION

The material processed for the coarse aggregate tests conforms approximately to the gradation requirements of Granular A. The aggregate samples were prepared using a large spinning riffler, developed and built by staff at the MTO Downsview Laboratory (refer to Figures 2 and 3 of Report MI-179, February 2000). A bobcat loader was used to fill an aggregate bin with small scoops from the stockpile, and the material was fed along a conveyor belt to fill 30 identical bags (fitted with funnels) on a spinning turntable. It was found that 20 to 26 revolutions of the turntable were required to fill each bucket to 31 ± 2 kg of Granular A. This resulted in more homogeneity of the samples than would normally be the case using other techniques. In total, five hundred 31 ± 2 kg samples were prepared for the tests on Granular A, and randomized for distribution to participating laboratories. The participants were responsible for the preparation of their own fine aggregate samples (3.08 and 4.08) from the two bags of Granular A supplied.

However, the number of revolutions of the turntable required for HL stone (coarse aggregate) to fill each bucket to approximately 20 ± 2 kg was found to be lower (18 to 24) than that of the Granular A. In total, five hundred 20 ± 2 kg samples were prepared for the coarse aggregate tests using HL stone, and randomized for distribution to participating laboratories.

The soil was air-dried, processed passing 2.0 mm using a Fritsch Soil Mill Pulverizer, and placed in 20 kg buckets. Individual scoops were collected from each bucket and placed in a separate container. The material from the container was then transferred to the hopper of a small spinning riffle splitter. The hopper of the spinning riffle used is capable of filling 24 identical 2 kg containers per run. This method was used to create uniform 20 kg buckets. The correlation material was then prepared by obtaining representative samples from a 20 kg bucket. The material collected from the 20 kg bucket was then transferred to the hopper of the spinning riffle and the 500 g correlation samples were prepared. The samples were then randomized for distribution to participating laboratories. The use of a spinning riffler ensured that, as far as possible, each sample was identical to every other sample. It has been found that this is the best technique for minimizing sample bias.

3.3 NOTES ON INDIVIDUAL TESTS

For each test, comments have been made pertaining to the variation illustrated by the scatter diagram. The technique used to test for outliers is stated and, where possible, reasons for the outlying observations are offered. It is important to keep in mind that there are many variables influencing laboratory testing.

A summary of the statistical data is presented in the Multi-Laboratory Precision Tables found in Appendix C. Besides the comparison made to ASTM precision statements, comparison of the variation between test periods is made for each of the tests. Because the materials usually differ from year to year, it is emphasized that the comparison between years should be used only as a guide. It is important to note that the yearly use of different materials will have some effect on the variation exhibited in some tests, while it will have relatively little effect on others. For example, the magnesium sulphate soundness test normally exhibits increased variation as higher mean loss is reported. A coarse aggregate sample having an average mean loss of twenty percent would likely show more variation than a coarse aggregate sample having an average mean loss of ten percent. On the other hand, a sieve analysis could be performed on those same two aggregates, with the percent passing each sieve and the variation being remarkably similar for the two samples.

3.4 PROFICIENCY SAMPLE TESTS

3.4.1 Wash Pass 75 µm (Coarse Aggregate) – Test No. 1

Two hundred and thirteen laboratories participated in this test in 2008. Three outliers were identified and rejected using the critical value method. The standard deviations obtained in 2008 are consistent with that of the values reported in the past three years, and the multi-laboratory variation published by ASTM for aggregates with less than 1.5% material finer than 75 µm. The scatter diagram shows a combination of random variation and laboratory bias for some laboratories. The laboratories that are identified as outliers or with a zero rating should examine their test procedure more closely, especially the achievement of constant dry mass at the beginning and end of the test.

3.4.2 Sieve Analysis (Coarse Aggregate) – Test Nos. 2-6

These tests represent the coarse aggregate portion of the Granular A sample gradation. Tests 20-25 carried out on the material passing 4.75 mm sieve as prepared by the participants (samples 3.08 and 4.08) represent the remainder of the gradation. The data is presented in percent passing format and is compared to precision statements developed in the same format by Vogler and Spellenberg[7].

The Granular A samples supplied for the sieve analysis tests consisted of approximately 50% of the material retained on 4.75 mm sieve, and conform to the grading of materials (Granular A) used in the past years' MTO Aggregate and Soil Proficiency Sample Testing Programs, with the exception of 2007. In 2007, the gradings of coarse (HL stone) and fine (concrete sand) aggregates were determined from two separate coarse and fine aggregate samples supplied. The gradings reported in 2007 for Test Nos. 2-6 represented only the coarse aggregate compared to the combine gradings of coarse and fine aggregates in 2008.

The samples were prepared with a large spinning riffler that is described in Section 3.2. This method of preparation minimizes the sample variation and has resulted in no observable average gradation difference between samples 1.08 and 2.08. The variations found in 2008 for the coarse sieves are consistent with that of the values obtained in the 2005 and 2006 studies. However, the standard deviations obtained for all of the sieves, except 19.0 mm sieve, are significantly lower than that of the expected variations given in the ASTM precision statements.

Two hundred and thirteen laboratories performed the sieve analysis test in 2008. Outliers were eliminated using the critical value method. Successive scatter diagrams show a fairly uniform distribution of points about the mean (i.e. a random variation with laboratory bias for some laboratories). The number of outliers identified varies from sieve to sieve, and it ranges from three for 19.0 mm, 13.2 mm, and 9.5 mm sieves to a maximum of seven for the 4.75 mm sieve.

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7 Vogler, R.H., Department of Transportation, Michigan, AASHTO Technical Section 1c; T27 and Spellenberg, P.A., AASHTO Materials Reference Laboratory; Unpublished Paper.

Possible reasons for outlying observations include factors that impact the measurement process such as sieve condition (state of repair and cleanliness), efficiency of the sieving process and apparatus, initial sample mass, and mass on a given sieve. If your laboratory has performed poorly in this test period, you should inspect your sieves (use CAN/CGSB-8.1-88 or ASTM E11 as guides) and your sieve shaker(s) thoroughly, and, once satisfied that they are in order, perform a sieving efficiency test (MTO Test Method LS-602, Revision No. 23) to pinpoint any problems.

3.4.3 Los Angeles Abrasion Loss (Coarse Aggregate) – Test No. 8

Only eleven laboratories participated in this test. One outlier was detected by the use of iterative technique. Considering the number of observations (11) used, the analysis may not yield a meaningful or representative statistical data. The lower left and upper right quadrants together account for seven of the eleven points, which is evidence of significant laboratory biases. This test shows systematic variation, as was found in previous years. However, the variations in 2008 are consistent with that of the values found in the past studies, and the coefficient of variation published in the ASTM precision statement.

ASTM precision statements for 19.0 mm maximum size coarse aggregate, with percent loss in the range 10% to 45%, give a multi-laboratory coefficient of variation of 4.5%. Therefore, results from two different laboratories should not differ by more than 12.7%. The mean in this test (22.2%) is in the range of values for which ASTM data was established. This year's coefficient of variation (average 5.3%) is consistent with that of the value, 4.5%, given in the ASTM precision statements.

3.4.4 Relative Density (Coarse Aggregate) – Test No. 9 and Absorption (Coarse Aggregate) – Test No. 10

Ninety-seven laboratories participated in these tests in 2008. Three laboratories in Test No. 9 and two laboratories in Test No. 10 were eliminated using the critical value method. The standard deviations obtained for bulk relative density (Test No. 9) are consistent with that of the values found in the past three years, and are considerably less than the values given in the ASTM precision statements. A similar trend was observed in the absorption test (Test No. 10). The variations obtained in 2008 are similar to that of the values reported in 2006 and 2007, and are almost two-third of the values reported in 2005 and that of the precision estimate provided in ASTM. The latest version of ASTM C127-04 does not provide precision estimate for the absorption test. The expected variation shown on the precision table in Appendix C is based on the previous publication C127-88. The scatter diagrams for both of these tests show a random variation with laboratory bias for some laboratories.

3.4.5 Magnesium Sulphate Soundness (Coarse Aggregate) – Test No. 11

Thirty-six laboratories reported results for this test in 2008. No outlier was identified by the use of critical value method or iterative technique. The scatter diagram shows a strong laboratory bias and all the points, with the exception of five (86%), are accounted in the lower left and upper right quadrants. This test has historically shown high coefficients of

variation due to the difficulty of maintaining solution of the correct density and insufficient drying by some laboratories. The coefficient of variations obtained in 2008 (32.9%) is consistent with the value reported in 2007 (32.3%), but slightly higher than that of the values reported in 2005 (24.9%) and 2006 (28.6%). The mean in this test (4.3%) is well below the values for which ASTM precision estimate was established, but the variations are slightly higher than the value published in the ASTM precision statements. ASTM reports a multi-laboratory coefficient of variation of 25% for coarse aggregate with percent loss in the range of 9% to 20%.

3.4.6 Percent Crushed Particles – Test No. 12 and Percent Cemented Particles – Test No. 7

Two hundred and thirteen laboratories performed the percent crushed particles test in 2008. Eleven outliers were selected by employing the critical value method. Variation (3.7%) in 2008 is significantly lower than the values (4.3% to 6.40%) reported in the past three years and the value (6.0%) obtained during the 1989 MTO workshop. The mean in this test (63.4%) is within the range of values (50% to 75%) for which the MTO precision statement was established. The scatter diagram shows a random variation and operator bias for some laboratories. The samples distributed did not contain any cemented particles; therefore the percent cemented particles test was not evaluated this year. ASTM has a very similar test method (D5821) but has not conducted interlaboratory studies to determine precision and currently publishes precision data (standard deviation of 5.2% for a mean value of 76.0%) obtained from MTO study.

3.4.7 Percent Flat and Elongated Particles – Test No. 13

The determination of a flat and/or elongated particle is dependent on operator skill and judgement in using the measurement tool. The ASTM and CSA procedures use a proportional calliper device to measure the *greatest* length or width to thickness ratio. The MTO procedure previously measured the *mean* length or width to the *mean* thickness (MTO Laboratory Manual Revision 15 and earlier). The MTO procedure (Revision 16 and up) has been modified to agree with the ASTM definition. All participants should be using the latest MTO version of the test.

One hundred and seventy six laboratories reported results for this test in 2008. The critical value method was used to reject six outliers. ASTM and CSA do not report precision for this test method. MTO Test Method LS-608, Revision No. 24 provides estimates of precision for coarse aggregate passing 19.0 mm and retained on 4.75 mm. The coefficient of variation, 50%, obtained in 2008, is significantly higher than that of the values reported in 2005 (44.9%) and 2006 (37.1%), and the precision estimate (41%) published by MTO. Further, the coefficient of variation in 2008 is almost twice that of the value (28.2%) obtained in 2007. The lower variation in 2007 may have resulted from the simplified test procedure that was used. In 2007, only the material passing 13.2 mm and retained on 4.75 mm was tested as a single sample. The test procedure adopted did not require separation of samples into number of fractions and calculation of weighted average.

The scatter diagram provided in the Appendix D1 shows a combination of random variation and laboratory operator bias for some laboratories. In general, laboratories that reported values in excess of 6.5% should critically examine their equipment and procedure.

3.4.8 Petrographic Number (Concrete) – Test No. 14

The coarse aggregate examined in 2008 was Granular A from Goodwood Pit owned by Lafarge Canada Inc. (MTO MAIDB No. N02-089).

Analysts from 28 laboratories examined samples 1.08 and 2.08 (full fraction) and submitted worksheets showing subdivision according to rock type and quality. Laboratories 13, 15, and 59 used the same analyst as did 101, 203, and 80. Laboratories 150 and 79 also used the same analyst. Two laboratories were excluded from the analysis for not adhering to correct test procedure. One outlier was identified by the use of iterative technique.

Laboratory 23 made a minor calculation error on the worksheet, resulting in a petrographic number for sample 2.08 that was nearly two points less than the actual number. However, the corrected value does not cause exclusion of the lab as an outlier.

In this test period, the coarse aggregate was partly crushed gravel containing mostly carbonate rocks. The carbonate component was most likely derived from the Ordovician limestone located north of the source. Precambrian gneiss and granitoid rocks derived from the Grenville subprovince to the north was a significant secondary component of the sample.

Overall, the amount of good quality aggregate in the sample averaged 94%. The amount of 'good quality' carbonate averaged 74% with a range for experienced observers from 70 to 78%. However, there was some disagreement about proportions assigned to the various types within the good category. Some recognized significant amounts of the surfaced weathered/medium hard category (Type 20), finding up to 76%, but most found far lower amounts.

Siliceous rocks of Precambrian origin were the second major component of the sample with most operators placing an average of 17% into the gneiss (Type 04) and granite (Type 08) categories. Trace amounts of quartzite (Type 05), volcanic (Type 07), trap (Type 09), and quartz veins (Type 10) were also indicated by many operators.

In the fair group, the most commonly reported rock type was soft or slightly shaley carbonate (Type 35) with a range from 0 to 11% and an average of 2.5%. The second most common rock types were brittle gneiss (Type 25) and brittle granitoids (Type 27) with averages of 0.9% and 0.3%, respectively. Rock types 40, 41, and 42 were reported as present by several analysts, however, amounts varied considerably from operator to operator.

In the poor group, the most commonly reported were small amounts of shaley carbonate (Type 43) and friable gneiss (Type 50).

Trace amounts of shale and clay were the most commonly observed deleterious components. The grey to grey-brown shale is likely derived from the underlying Whitby Formation.

The similar ASTM standard for this test, C295, does not report a petrographic number and has no precision statement.

3.4.9 Petrographic Analysis (Fine Aggregate)

The fine aggregate examined in 2008 was concrete sand from Erie Sand & Gravel, Leamington Pit (MTO MAIDB No. E02-020).

Analysts representing ten laboratories examined samples 1.08 and 2.08, and submitted work sheets showing subdivision according to rock/mineral type (silicate, carbonate, shale, mica, chert, contamination, and cementation) and sieve size. Laboratories 15 and 59 used the same analyst, as did 80, 101, and 203.

The samples contained an average of approximately 47% silicate, 44.5% carbonate, 5% shale, 2.5% chert, and 1% mica. Laboratory 47 reported average values for carbonate content greater than 60% and average silicate contents less than 30%. Laboratory 27 reported average silicate rock and mineral contents greater than 70% and average carbonate contents less than 25%. Laboratory 27 also chose to perform a more complete mineralogical assessment of the sample provided, not adhering to the material types as listed on report form PH-CC-437 in MTO LS-616.

A need for Laboratories 27 and 47 to modify their rock/mineral type classification system is indicated. Only ten laboratories have reported results for this test. Because of this, no statistical analysis was performed. The similar ASTM standard for this test, C295, has no precision statement.

3.4.10 Micro-Deval Abrasion (Coarse Aggregate) – Test No. 16

Sixty-nine laboratories reported results for this test in 2008. The test method requires reporting of control sample results to demonstrate that the testing process is in control. This year, one laboratory reported control sample results outside the established range and the lab was excluded from the analysis. Three outliers were rejected using the iterative technique.

The precision statements in the MTO LS-618 was revised in 2007 and published in Revision No. 24. The multi-laboratory coefficient of variation of 5.6% published in the latest revision is for 19.0 mm maximum size aggregate with abrasion losses in the range from 5% to 20%. The mean loss in this year test was 14.7%. The average coefficient of variation of 5.5% obtained in 2008 is consistent with the value published in LS-618, and that of the values reported in the past three years (5.5% to 6.5%). The scatter plot for this test shows a combination of random variation and laboratory bias for some laboratories.

3.4.11 Freeze-Thaw Loss – Test No. 17

Fifty-one laboratories reported results for this test in 2008. The test method requires reporting of laboratory control sample losses to demonstrate that the testing process is in control. This information is used to alert the laboratory to testing deficiencies. Without testing of the reference material, the test is invalid (see MTO Test Method LS-614, Section 9.1). This year, all of the participants have reported control sample results within the established range. Two outliers were selected using the iterative technique.

The precision statements in MTO LS-614 were revised in 2007 based on the proficiency sample test results collected for a period of nine years from 1998 to 2006. The multi-laboratory coefficient of variation of 21% published in the MTO LS-614, Revision No. 24 is for coarse aggregate passing 19.0 mm and retained on 4.75 mm sieves, with freeze-thaw losses in the range of 5% to 18%. The coefficient of variation obtained in 2008 (21.3%) is consistent with the value, 21%, published in the MTO precision statements, and the values reported in the 2005 (20.8%) and 2007 (20.8%) studies. However, the variation is noticeably higher than the value (13.1%) reported in 2006. All of the points on the scatter plot (82%), with the exception of nine, are accounted in the lower left and upper right quadrant, indicating a strong laboratory bias.

The results reported by the two outlier laboratories deviate considerably from the mean values. It is likely that there are two main reasons for the widespread of their data: insufficient damage caused by freezing, which may be due to freezing too rapidly, or difference in sieving intensity. The laboratories identified as outliers should modify their processes to try and achieve losses closer to the mean loss of the control aggregate. MTO LS-614, Revision 22 (Appendix 1) in the MTO Laboratory Testing Manual gives a procedure for determining and adjusting sieving time for quantitative analysis. It is possible that increased use of this procedure to adjust sieving time is having a positive effect on performance of laboratories in this test.

3.4.12 Sieve Analysis (Fine Aggregate) – Test Nos. 20-25

The samples for this procedure were prepared by the participants from the material passing the 4.75 mm sieve of the coarse aggregate gradation. This process closely follows the normal testing procedure in which the laboratory prepares its own test samples from the field sample. The scatter diagrams for the fine aggregate sieve analysis show random variation with little laboratory bias. The standard deviations of the fine sieves in 2008 are consistent with that of the values reported in 2005 and 2006 studies, and the multi-laboratory variations published in the ASTM C136 precision statements. Unlike in 2005 and 2006, the sieve analysis of fine aggregate in 2007 was performed on material supplied separately for fine aggregate tests. The gradings reported were based only on the mass of fine aggregate test sample. For these reasons, the variations obtained in 2008 cannot be compared with that of 2007.

As in previous interlaboratory studies, it was found that the precision of the test varies as a function of the amount of material retained on any sieve. The smaller the amount of material retained on the sieve, the more efficient the sieving process and the better the precision.

When there is a small amount of material on a sieve (one layer of particles or less), the particles have a greater chance of falling through the sieve in a given time.

The number of outliers identified varies from sieve to sieve, and it ranges from three for 1.18 mm sieve to a maximum of eight for the 75 μm sieve. Outlier labs with a very low percent passing the 75 μm sieve should inspect their sieves, as low percent passing may be the result of the sieve being blinded when washing the sample. An ineffective washing process will also result in a low percent passing the sieve.

3.4.13 Relative Density (Fine Aggregate) – Test No. 27 and Absorption (Fine Aggregate) – Test No. 28

Prior to 2005, the ministry was using MTO Test Method LS-605 for the determination of bulk relative density and absorption of fine aggregates throughout its correlation studies. The participants in the 2005, 2006, and 2007 programs were asked to test Sample 1 (1.05, 1.06, and 1.07) according to MTO LS-605 and Sample 2 (2.05, 2.06, and 2.07) in accordance with the procedures described in ASTM C128. MTO LS-605 follows ASTM C128, except that it requires the removal of materials finer than 75 μm from the test specimen. The significant difference between the methods is that MTO LS-605 requires the test specimens to be prepared in duplicates and washed on the 75 μm sieve until all of the material finer than 75 μm is removed. As a consequence, the test results reported in 2005, 2006, and 2007 were obtained for the same materials with the only difference being the presence or absence of fines passing the 75 μm sieve. The presence of material finer than 75 μm in the test specimens can result in lower densities and higher absorption.

Participants in the 2008 program were asked to test both samples 1.08 and 2.08 according to the MTO LS-605. Ninety-four laboratories reported results for these tests. Five outliers for Test No. 27 and three outliers for Test No. 28 were selected using the critical value method. As in previous years, greater variation exists in this test compared to the relative density test on coarse aggregate. It is imperative that differential drying of the various sized particles be avoided by *constant* stirring of the sample under the air current during the drying process. As short as 30-second periods of rest can be detrimental to the outcome of the test results. Differential drying of the particles is known to cause premature collapse in the cone test used to judge the saturated surface dry state. The resulting test observations are lower relative densities and higher absorption values.

The standard deviations obtained in 2008 for both relative density and absorption are slightly lower than the values that were reported for Samples 1.06 and 1.07 tested using the MTO test procedure. In addition, the multi-laboratory variations obtained in 2008 are significantly lower than that of the values published in the ASTM precision statements. The scatter plots for both tests show a combination of random variation and laboratory bias for some laboratories.

3.4.14 Amount of Asphalt Coated Particles in Coarse Aggregate – Test No. 30

Two hundred and thirteen laboratories reported results in 2008. Three laboratories were identified as outliers using the critical value method. The scatter plot shows a combination of random variation and laboratory bias for some laboratories. The latest revision of this test method (Revision No. 24) provides precision estimate for 19.0 mm maximum size coarse aggregate mixed with asphalt coated particles in the range of 25% to 45%. The coefficient of variation obtained in 2008 (16.2%) is consistent with the value reported in 2007 (16%), but noticeably higher than that of the values (8.3% and 11.8%) reported in 2005 and 2006, and the precision estimate (9.6%) published in the MTO LS-621. Laboratories that reported values of less than about 25% and above 49% should critically evaluate their interpretation of the definition and re-examine their samples. There is no comparable or similar ASTM test procedure.

3.4.15 Moisture-Density Relationship (One-Point Method) – Test Nos. 31-33

The finer portion of the Granular A (i.e. material passing the 4.75 mm sieve) was used for this test. The samples for this test procedure were prepared by the participants from the bulk Granular A samples supplied.

One hundred and fifty-two laboratories reported results for this test in 2008. One outlier for Test Nos. 31 and 32, and six outliers for Test No. 33, were rejected using the critical value method. The variations obtained in 2008 for Test Nos. 31 and 32 are slightly higher than those of the values reported in the previous three years, but the value obtained for Test No. 33 is consistent with the values reported in the past three years. However, the standard deviations obtained for all three parameters (i.e. wet density, dry density, and optimum moisture content) are slightly higher than the precision estimates published in MTO LS-623, Revision No. 24.

The majority of the points in the scatter diagrams are accounted in the lower left and upper right quadrant of the plots, indicating strong laboratory bias. The possible causes for the strong laboratory bias may be operator error and the use of an improper mould, even though the participants were requested to use only the 152.4 mm diameter mould. This test also requires significant operator skill to obtain the point within the band in the first attempt. Those laboratories with poor ratings should examine their equipment and procedure to discover the causes for this variation. There is no ASTM precision statement for this test.

3.4.16 Micro-Deval Abrasion (Fine Aggregate) – Test No. 34

Participants in this test were asked to prepare their own sample from the bags of bulk Granular A supplied. Sixty-nine laboratories participated in this test in 2008. The test method requires reporting of control sample test results to demonstrate that the testing process is in control. This year, all of the laboratories, except one, reported control sample results within the range established for the material. This lab was manually removed from the statistical analysis.

The precision statements of this test method were revised in 2007, and the revised multi-laboratory coefficient of variation was published in MTO Test Method LS-619, Revision No. 24. The coefficients of variations of 7.4% for Sample 1.08 and 6.5% for Sample 2.08 obtained in 2008 are noticeably lower than the precision estimate (8.7%) published in MTO LS-619. In addition, the co fficients of variations obtained are consistent with the range of values (5.7% to 7.3%) reported in the past three years.

Six outliers were selected by the use of iterative technique. Eighty-five percent of the data points are located in the lower left and upper right quadrant of the scatter diagram indicating a strong laboratory bias.

3.4.17 Particle Size Analysis of Soil – Test Nos. 40-45

The ministry has been using the MTO Test Method LS-702 since 2000 for its annual testing program. The laboratories participating in this test have now gained experience with this test procedure. Based on the data sheets submitted by the laboratories, all of the laboratories performed the test in accordance with MTO LS-702. Seventy laboratories participated in the hydrometer test in 2008. Test No. 40 is reported for information purposes only, because 97% of the participants reported 100% passing 2.00 mm sieve. Outliers were selected using the iterative technique.

Successive scatter diagrams for this test show significant laboratory biases. The standard deviations obtained in 2008 for Test Nos. 41 and 42 are significantly lower than those of the values reported in the 2005 to 2007 studies. However, the variations obtained for Test Nos. 43, 44, and 45 are consistent with the results reported in the past three years.

The laboratories that are identified as outliers should examine their equipment and procedure very carefully to ensure that all is within specification and the procedure is followed exactly.

3.4.18 Atterberg Limits of Soil – Test Nos. 46-48

Eighty laboratories reported results for Atterberg limit tests in 2008. Three outlier laboratories for liquid limit and four for plastic limit test were identified using the iterative technique. The scatter plots for both liquid and plastic limit tests and plasticity index show strong laboratory bias. Both liquid and plastic limit tests require significant operator skills, and good condition and calibration of the apparatus. The variations observed are characteristics of these tests. Close attention to the condition and calibration of the liquid limit apparatus and employing skilled technicians may reduce the laboratory biases.

The variations obtained for liquid and plastic limit tests in 2008 are consistent with those of the values reported in the 2007 study. Further, the standard deviations obtained for plastic limit and plasticity index are consistent with the values published in the ASTM precision statements. However, the variations obtained for liquid limit test are considerably higher than the precision estimate published in ASTM D4318.

3.4.19 Specific Gravity of Soils – Test No. 49

The participants were requested to perform this test according to MTO Test Method LS-705. This test method requires that the test be performed on a minimum of three specimens, and the range (the difference between the largest and smallest value) of the specific gravity of all three specimens determined shall be within 0.02. The test must be repeated if the range exceeds the specified limit. The laboratories that report results with the range in excess of 0.02 are manually deleted from the analysis and identified as outliers. No lab was removed this year for exceeding the specified limit.

Fifty-eight laboratories reported results for this test in 2008. Four outliers were identified using the iterative technique. Eighty-six percent of the plots are located in 1st and 3rd quadrants of the scatter diagram showing a strong laboratory bias. Several steps in this test procedure can influence the results, particularly the equipment and method employed for preparation of test specimen, as well as for removal of air entrapped in the pycnometer or flask. The possible cause for the bias may be because the laboratories do not fully comply with the test procedures. Laboratories finding themselves in this situation should examine their equipment and procedure very carefully.

The standard deviations obtained in 2008 are consistent with the results reported in the past three years. MTO LS-705 is similar to that of AASHTO T 100, which reports a multi-laboratory standard deviation of 0.04. As in the past three studies, the standard deviations obtained in 2008 are also significantly lower than that of the precision estimate published in the AASHTO T 100.

3.5 SUPERPAVE CONSENSUS PROPERTY TESTS

3.5.1 Uncompacted Void Content (FA) – Test No. 95

The participants were asked to perform the test in accordance with MTO Test Method LS-629, using the fine aggregate prepared by splitting the material passing 4.75 mm sieve. This test method is a modified version of AASHTO T 304, and was developed for the purposes of determining compliance with Superpave consensus properties. MTO LS-629 follows Method A of AASHTO T 304, except for the preparation of the test specimen to be used in the determination of bulk specific gravity of fine aggregates. The significant difference between the methods is that MTO LS-629 requires the test specimens be washed on the 75 µm sieve until all the material finer than 75 µm is removed. In addition, MTO LS-629 specifies that the bulk relative density is determined using the graded sample and not the individual size fraction method described in Clause 9.4 of AASHTO T 304. Further, the participants were advised to compute the uncompacted void contents of Samples 1.08 and 2.08 using the bulk relative densities reported for Test No. 27 (i.e. the densities determined according to MTO LS-605).

Fifty-eight laboratories submitted results for this test in 2008. Six laboratories were identified as outliers using the iterative technique. The scatter diagram shows a combination of random variation and laboratory bias for some laboratories. The standard deviations obtained in 2008 (0.57 and 0.54) are slightly lower than the values obtained for Samples 1.06 (0.68) and 1.07 (0.70) in 2006 and 2007, respectively. The standard deviations obtained for both samples are noticeably higher than the value (0.33%) published in the ASTM precision statements for graded standard sand. The estimates of precision in ASTM are based on graded sand as described in ASTM C778, which is considered rounded, and is graded from 600 µm to 150 µm, and may not be typical of the samples that were used in this testing program.

ASTM C1252 suggests that a difference in relative density of 0.05 will change the calculated void content by about one percent. There is marked improvement in the multi-laboratory variation in 2008. The improvement may have resulted from the changes made to MTO Test Method LS-605 in 2006. The laboratories that are identified as outliers must review their test procedures and the skill of the technician.

It should be noted that adopting the revised procedure where the fine aggregate is washed before determining density will usually give a higher bulk relative density. This, in turn, will result in higher uncompacted void contents for fine aggregates with significant minus 75 µm fines contents. The impact on fine aggregates with low fines contents will be small since density will not normally change significantly.

3.5.2 Sand Equivalent Value of Fine Aggregate – Test No. 96

The participants were asked to prepare the fine aggregate sample for this test by splitting the material passing 4.75 mm sieve. Two alternate procedures for the preparation of test specimen (air-dry or pre-wet) are allowed in both ASTM and AASHTO methods. The participants were given the option of preparing the test specimen in accordance with either method.

Fifty-six laboratories participated in this test in 2008. No outlier was identified by the use of critical value method or iterative technique. The lower left and upper right quadrants of the scatter diagram together account for 91% of the points showing significant laboratory bias. The standard deviations obtained in 2008 (4.01 and 3.95) are slightly higher than the values reported in 2007 (3.49 and 3.75), but the values are significantly lower than the multi-laboratory precision value (8.0) published by ASTM for samples with sand equivalent value less than 80.

3.5.3 Percent of Fractured Particles in Coarse Aggregate – Test No. 97

The samples supplied did not contain adequate material retained on 19.0 mm sieve. Because of this, the participants were advised to perform the test on coarse aggregate passing the 19.0 mm sieve only.

Sixty laboratories submitted results for this test in 2008. Two outliers were detected using the iterative technique. The scatter diagram shows a strong laboratory bias. The average mean values obtained by the ASTM method (64.0%) and MTO versions (63.3%) of the test on the same aggregate differ by only 0.7%, and the standard deviations obtained by ASTM (3.8%) is identical to that of MTO version (3.8%). The ASTM test method is very similar to MTO Test Method LS-607, but ASTM has not conducted interlaboratory studies to determine precision and currently publishes statistical data provided by MTO. The variations in 2008 (3.8% and 3.7%) are consistent with the values obtained in 2006 and 2007, and are noticeably lower than that of the value (5.2%) published in ASTM precision statements.

3.5.4 Percent Flat and Elongated Particles in Coarse Aggregate – Test No. 99

The samples supplied did not contain adequate material retained on 19.0 mm sieve. As a result, the participants were advised to perform the test on coarse aggregate passing the 19.0 mm sieve only, using a ratio of 5:1.

Sixty laboratories performed this test in 2008. Four outliers were detected using the iterative technique. The standard deviations obtained in 2008 are significantly lower than that of the values reported in the past three years of studies. However, the average coefficient of variation of 63.5% obtained in 2008 is consistent with the range of values (50.7% to 60.5%) obtained in 2005 and 2006. As indicated in Section 3.4.7, lower coefficient of variation (43.0%) obtained in 2007 may have resulted from the simplified test procedure that was used. There is no ASTM precision statement for this test.

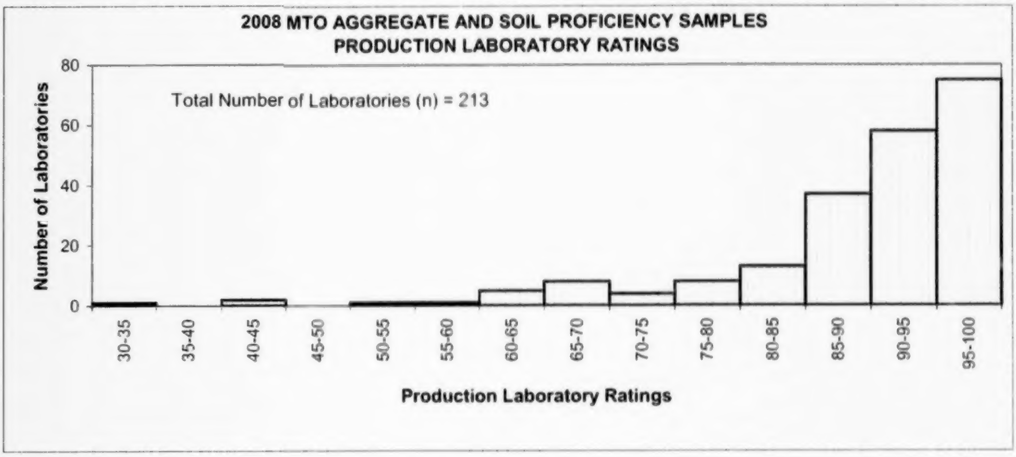
4. Laboratory Rating System

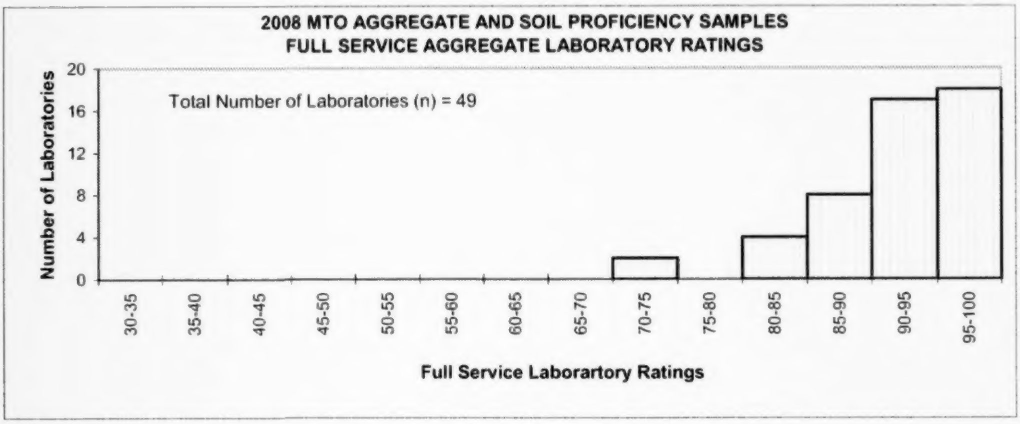
The laboratory rating system assigns separate ratings for low complexity (production) aggregate laboratories, high complexity (full service) aggregate laboratories, and for soil laboratories. Low complexity laboratories are required to carry out wash pass 75 µm, gradation, percent crushed particles, percent asphalt coated particles, and optional, percent flat and elongated particles. In addition to those low complexity tests, high complexity laboratories must carry out micro-Deval (coarse and fine), freeze-thaw, and/or magnesium sulphate soundness, relative density and absorption (coarse and fine). Forty-nine high complexity (full service) aggregate laboratories participated in the program in 2008. Soil laboratories are required to carry out particle size analysis, Atterberg limits, and specific gravity of soil. Fifty-seven laboratories participated in all of the soil tests in 2008.

A similar laboratory rating system is also used for assigning laboratory ratings for Superpave aggregate laboratories. The laboratories are required to perform all four consensus property tests (i.e. uncompacted void content of fine aggregate, sand equivalent value of fine aggregate, percent fractured particles in coarse aggregate, and flat and elongated particles in coarse aggregate). Fifty-six laboratories reported results for all of the consensus property tests.

The rating system gives a maximum of 10 for each test, (e.g. 5 for wash pass 75 µm on sample 1.08, plus -5 for wash pass 75 µm on sample 2.08, equals 10 (the negative sign indicating a test result less than the mean is ignored). Some tests that are normally reported together are averaged and given a maximum of 10. The relative density and absorption (coarse and fine), one-point Proctor values (maximum wet and dry density, and optimum moisture content), particle size analysis of soils, and Atterberg limits are treated in this manner. Because of the large number of individual test ratings in the gradation results, the ratings are modified so as not to unduly bias the overall balance between various tests. The ratings for each sieve size are added and then divided by the number of sieves for which results were reported, and multiplied by 3 to give a laboratory rating with a maximum of 30 for this test. Aggregate, soil, and Superpave laboratory ratings are given in Figures 2 and 3. The laboratory rating system data is reported in the Appendices E1, E2, E3, and E4.

Laboratory ratings are given in the covering letter accompanying this report to individual laboratories. A poor or good rating for a laboratory in one year is an indication of how that laboratory performed in the proficiency study, and may not be a reflection of how the laboratory performs year round. A consistently poor rating over two or more years may be cause for serious concern.





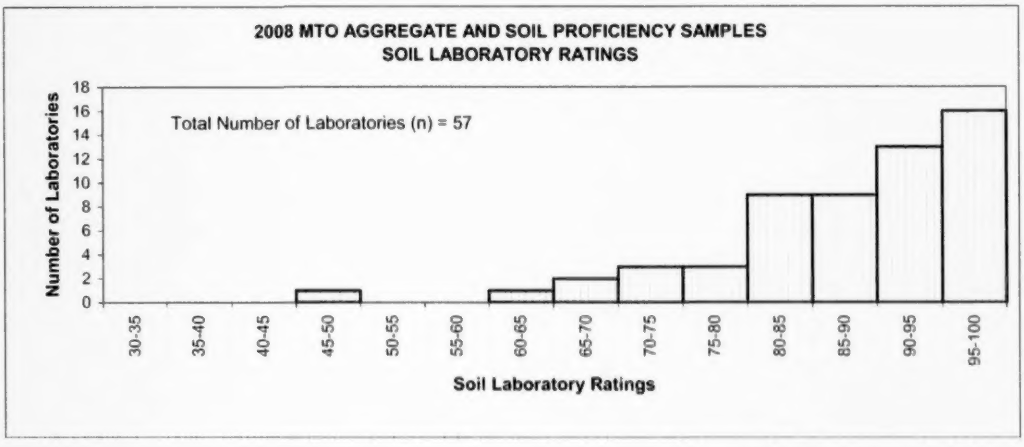


Figure 2. Laboratory Ratings

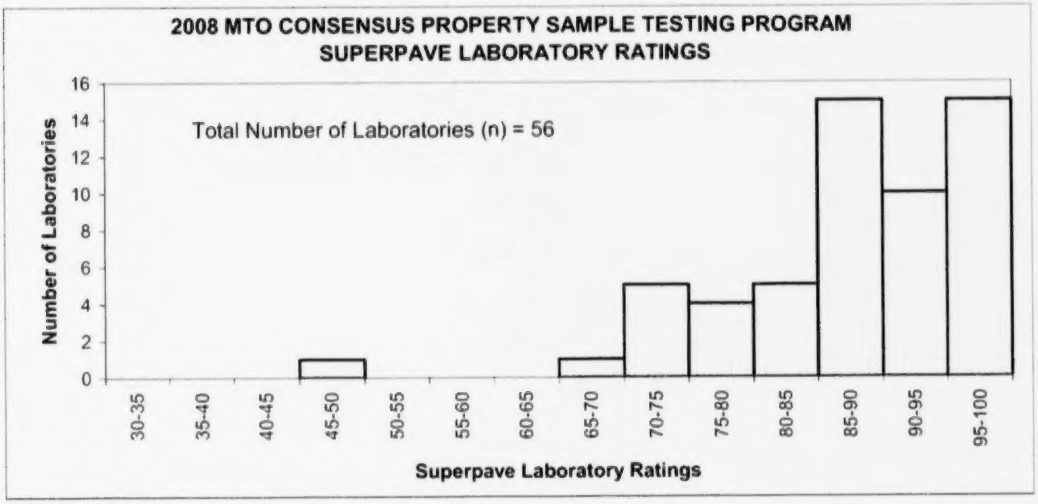


Figure 3. Superpave Laboratory Ratings

5. Conclusions

The method of proficiency sample preparation employed by MTO resulted in no significant mean gradation differences between samples 1.08 and 2.08. The differences in mean, as well as in the standard deviations between pairs of samples for both coarse and fine sieves, are none to negligible. Based on the results, it may be concluded that the sample preparation method employed is very effective and capable of producing a uniform and nearly identical material at reasonable cost.

The majority of the aggregate and soil test results of the 2008 Aggregate and Soil Proficiency Sample Testing Program compare favourably with the results of previous studies. In some cases, the variations show noticeable improvement over previous years' results and the precision estimates of those tests where MTO or ASTM precision statements are available. The scatter diagrams for the majority of the aggregate tests show either random variation or a combination of random variation and laboratory bias for some laboratories.

Two hundred and three of the laboratories that participated in the aggregate tests are CCIL Type C (low complexity tests) certified, and forty-eight of those are certified for high complexity tests (Type D). CCIL inspects the certified laboratories for quality control procedures, ability of technicians, and condition and calibration of the equipment at about eighteen month intervals. Most of the aggregate tests (Type C and Type D) are showing general improvement in variation due to the on-site laboratory inspection by CCIL at regular intervals, proficiency sample testing, and due to an increased awareness of the importance of proper testing and quality control procedures implemented by CCIL.

The variations found in 2008 for the soil tests are consistent with the values reported in the last three years' studies, but the scatter diagrams still show strong laboratory biases. The results of soil tests are significantly influenced by operator skills, testing environment, and the condition and calibration of the equipment. Thirty-four of the fifty-seven laboratories that participated in the soil tests in 2008 are on the MTO Approved List. The laboratories that are on the list were inspected by MTO staff prior to approval. Most of the laboratories approved were inspected about five to six years ago on a voluntary basis and few re-inspections[8] have been done to date.

The results of 2008 Superpave Consensus Property Tests show improvements in the performance of the laboratories. Further, the multi-laboratory precision, with the exception of uncompacted void content, is noticeably lower than the values published in ASTM precision statements. However, the scatter diagrams show strong laboratory biases. The laboratories that have participated in the program have been conducting consensus property tests for more than six years and have now gained experience in these tests. The improvements in the multi-laboratory variation of these tests may also likely be due to the on-site laboratory inspection by CCIL on regular intervals.

8 To arrange an inspection of your Soil Laboratory, please contact Mark Vasavithasan, Soils and Aggregates Section, Ministry of Transportation, phone (416) 235-4901, fax (416) 235-4101.

6. Recommendations

Although, there are noticeable improvements in the multi-laboratory variations, strong laboratory biases still remain in a number of test procedures. The laboratories that were identified as outliers and obtained zero ratings should examine the condition and calibration of equipment, testing procedures, and skills of the technicians. It is good practice to do this whenever a rating of 2 or less is obtained.

The results of the 2008 MTO Aggregate and Soil Proficiency Sample Testing Program suggest that most laboratories have performed satisfactorily. Laboratories that obtained relatively low ratings must focus on operator training, standardization and calibration of equipment, and improvements to laboratory environment in order to improve their performance.

For all of the tests that were included in this study, the equipment to be used is regulated by the test method itself. A good state of maintenance, repair, and correct calibration is sometimes lacking. It is hoped that the mandatory Quality System implemented by CCIL will encourage laboratories to conduct self-examination to ensure that they have the correct equipment and properly trained technicians. Laboratories will find that a well-documented and regular program of internal inspection, calibration, and testing of control or reference samples is beneficial to maintaining a high level of confidence in their results.

7. Acknowledgments

The authors wish to acknowledge the assistance and dedicated work of the laboratory staff of the Soils and Aggregates Section in the preparation of samples and performing the tests. We received considerable assistance from the laboratory staff of the Bituminous Section and the Concrete Section in the preparation of correlation samples for distribution.

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Appendix A: Glossary of Terms

Precision refers to the degree of mutual agreement between individual measurements on the same material. In other words, precision is a measure of how well the individual test results of a series agree with each other.

Accuracy refers to the degree of mutual agreement between a set of measurements with an accepted reference or 'true value'. This 'true' or reference value can be an assigned value arrived at by actual experiments.

Bias of a measurement process is a consistent and systematic difference between a set of test results derived from using the process and an accepted reference value of the property being measured. For the majority of aggregate and soil tests, there is no acceptable reference material, so bias is impossible to compute.

Critical Value is that value of the sample criterion which would be exceeded by chance with some specified probability (significance level) on the assumption that all the observations did indeed constitute a random sample from a common system of causes.

Coefficient of Variation expresses the standard deviation as a percentage of the mean, where:

$$C.V. = \frac{\text{std dev}}{\text{mean}} \times 100$$

Single operator precision (one-sigma limit (1s)) indicates the variability, as measured by the deviations above and below the average, of a large group of individual test results when the tests have been made on the same material by a single operator using the same apparatus in the same laboratory over a relatively short time.

Multi-laboratory precision (one-sigma limit (1s)) is a quantitative estimate of the variability of a large group of individual test results when each test has been made in a different laboratory and every effort has been made to make test portions of the material as nearly identical as possible. Under normal circumstances, the estimates of the one-sigma limit for multi-laboratory precision are usually larger than those for single-operator precision because different operators and different equipment are being used in different laboratories.

Acceptable difference between two results (difference two-sigma limit (d2s)) as an index of precision is the maximum acceptable difference between two results obtained on test portions of the same material tested by two different laboratories. The index, d2s, is the difference between two individual test results that would be equalled or exceeded in only one case in twenty in the normal and correct operation of the method. The index is calculated by multiplying the multi-laboratory standard deviation (1s) by the factor $2\sqrt{2}$ (2.83).

Sample mean or average is the sum of all observations divided by the total number of observations.

Median is synonymous with the middle and the **sample median** is the middle value of a list of test results when the observations are ordered from smallest to largest in magnitude. After rearranging the observations in increasing order (from most negative to most positive), the **sample median** is the *single middle value* in the ordered list, if n is odd, or the *average of the two middle values* in the ordered list, if n is even, where n equals the number of observations.

Standard deviation is the most usual measure of the dispersion of observed values or results expressed as the positive square root of the variance.

Variance is a measure of the squared dispersion of observed values or measurements expressed as a function of the sum of the squared deviations from the population mean or sample average.

Outlier is a measurement that, for a specific degree of confidence, is not part of the population. In this study, an outlier is generally three or more standard deviations from the mean, giving a confidence level of ninety-nine percent. If a laboratory test result is classified as an outlier, it means that something went wrong either with the sample or in the laboratory.

Appendix B1: List of Participants

2008 Participants List

Ministry of Transportation
Aggregate and Soil
Proficiency Sample
Testing Program

For further information on this program, contact:

Mark Vasavithasan (416) 235-4901, or
Stephen Senior (416) 235-3734

Participant	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
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AGS Associates Inc. Scarborough, ON Mr. A. Chohan Tel: 416 299-3655	✔	✔		✔	✔	✔	✔				✔	✔		✔	✔			
AME - Materials Engineering Brampton, ON Mr. Scott Crowley Tel: 905 840-5914	✔	✔		✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	
AME - Materials Engineering Gormley, ON Mr. Blaine Dobson Tel: 905 640-7772	✔	✔		✔	✔	✔	✔	✔		✔	✔	✔		✔	✔	✔	✔	
AME - Materials Engineering - Ottawa Brampton, ON Mr. Scott Crowley Tel: 905 840-5914	✔	✔				✔								✔				
AME - Materials Engineering (24-165) Brampton, ON Mr. Scott Crowley Tel: 905 840-5914	✔	✔				✔	✔							✔	✔			
AME - Materials Engineering (24-270) Brampton, ON Mr. Scott Crowley Tel: 905 840-5914	✔	✔				✔	✔							✔	✔			
AME - Materials Engineering (24-271) Brampton, ON Mr. Scott Crowley Tel: 905 840-5914	✔	✔				✔	✔							✔	✔			
AME - Materials Engineering (24-297) Brampton, ON Mr. Scott Crowley Tel: 905 840-5914	✔	✔				✔	✔							✔	✔			
AME - Materials Engineering (24-298) Brampton, ON Mr. Scott Crowley Tel: 905 840-5914	✔	✔				✔	✔							✔	✔			
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AME - Materials Engineering (24-912) Brampton, ON Mr. Scott Crowley Tel: 905 840-5914	✔	✔				✔	✔							✔	✔			
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2008 Participants List Ministry of Transportation Aggregate and Soil Proficiency Sample Testing Program For further information on this program, contact: Mark Vasavithasan (416) 235-4901, or Stephen Senior (416) 235-3734	LS-601 Wash Pass 75μm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
AMEC Earth & Environmental Ltd. Hamilton, ON Mr. John Balinski Tel: 905 312-0700	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
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AMEC Earth & Environmental Ltd. Cambridge, ON Mr. Lou Maier Tel: 519 653-3570	✔	✔		✔		✔					✔	✔		✔	✔	✔	✔	✔
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Bertrand Construction L'Original, ON Mr. Philippe Arnold Tel: 613 675-4614	✔	✔				✔	✔				✔	✔		✔				
BOT Construction Oakville, ON Mr. Vicks Sellathurai Tel: 905 827-3250	✔	✔				✔								✔	✔			
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C. Villeneuve Construction Hearst, ON Mr. Charles Harris Tel: 705 372-1838	✔	✔		✔		✔	✔							✔	✔			
C.T. Soil & Materials Testing Inc. Windsor, ON Mr. Thomas O'Dwyer Tel: 519 966-8863	✔	✔		✔	✔	✔	✔			✔	✔	✔		✔	✔	✔	✔	✔
Caledon Sand & Gravel Ltd. Caledon, ON Mr. Dean Glenn Tel: 519 927-5224	✔	✔				✔	✔							✔				
Capital Paving Inc. Guelph, ON Mr. Mark Latyn Tel: 519 822-4511	✔	✔				✔	✔							✔	✔			
CBM Aggregates - Aberfoyle Puslinch, ON Mr. Leigh Mugford Tel: 519 824-8169	✔	✔				✔	✔							✔				
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CBM Aggregates – Cambridge Cambridge, ON Mr. Leigh Mugford Tel: 519 740-3053	✔	✔				✔	✔							✔				
CBM Aggregates – Limehouse Limehouse, ON Mr. Leigh Mugford Tel: 416 806-3590	✔	✔				✔								✔				
CBM Aggregates – Pinewood Westwood, ON Mr. Leigh Mugford Tel: 705 295-6843	✔	✔			✔	✔	✔			✔	✔	✔		✔				

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Chung & Vander Dollen Engineering Limited, Kitchener, ON Mr. William Evans Tel: 519 742-8979	✔	✔		✔	✔	✔	✔			✔	✔	✔		✔	✔	✔	✔	✔
City of Sault Ste Marie Sault Ste Marie, ON Mr. John Sloan Tel: 705 946-9918	✔	✔				✔								✔				
CMT Engineering Inc. St. Clements, ON Mr. Tim Salter Tel: 519 699-5775	✔	✔				✔								✔	✔			
COCO Paving Inc. Windsor, ON Mr. Ernie Scerbo Tel: 519 948-7133	✔	✔		✔		✔	✔			✔	✔	✔		✔	✔		✔	
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Cruickshank Construction Ltd Morrisburg, ON Mr. Dan Byvelds Tel: 613 543-2978	✔	✔				✔	✔							✔	✔			
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2008 Participants List Ministry of Transportation Aggregate and Soil Proficiency Sample Testing Program For further information on this program, contact: Mark Vasavithasan (416) 235-4901, or Stephen Senior (416) 235-3734	LS-601 Wash Pass 75μm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
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District Municipality of Muskoka Bracebridge, ON Mr. Dave Wood Tel: 705 645-6764	✔	✔				✔								✔	✔	✔	✔	
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DST Consulting Engineers Inc. Thunder Bay, ON Mr. Scott Tozer Tel: 807 623-2929	✔	✔		✔		✔	✔			✔	✔	✔		✔	✔	✔	✔	✔
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2008 Participants List

Ministry of Transportation
Aggregate and Soil
Proficiency Sample
Testing Program

For further information on this program, contact:

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Stephen Senior (416) 235-3734

	LS-601 Wash Pass 75μm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
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Participant	LS-601 Wash Pass 75μm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
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2008 Participants List Ministry of Transportation Aggregate and Soil Proficiency Sample Testing Program For further information on this program, contact: Mark Vasavithasan (416) 235-4901, or Stephen Senior (416) 235-3734	LS-601 Wash Pass 75μm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
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2008 Participants List Ministry of Transportation Aggregate and Soil Proficiency Sample Testing Program For further information on this program, contact: Mark Vasavithasan (416) 235-4901, or Stephen Senior (416) 235-3734	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
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2008 Participants List

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For further information on this program, contact:

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	LS-601 Wash Pass 75μm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
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2008 Participants List

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For further information on this program, contact:

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Participant	LS-601 Wash Pass 75μm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
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Appendix B2: List of Participants

2008 Participants List Ministry of Transportation Superpave Aggregate Consensus Property Testing Program For further information on this program, contact: Mark Vasavithasan (416) 235-4901 or Stephen Senior (416) 235-3734	ASTM D 1252/AASHTO T 304 - Uncompacted Void Content of Fine Aggregate	ASTM D 4219/AASHTO T 176 – Sand Equivalent Value of Fine Aggregate	ASTM D 5821 – Percent of Fractured Particles in Coarse Aggregate	ASTM D 4791 – Percent Flat Particles, Elongated Particles or Flat & Elongated Particles in Coarse Aggregate
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2008 Participants List Ministry of Transportation Superpave Aggregate Consensus Property Testing Program For further information on this program, contact: Mark Vasavithasan (416) 235-4901 or Stephen Senior (416) 235-3734	ASTM D 1252/AASHTO T 304 - Uncompacted Void Content of Fine Aggregate	ASTM D 4219/AASHTO T 176 – Sand Equivalent Value of Fine Aggregate	ASTM D 5821 – Percent of Fractured Particles in Coarse Aggregate	ASTM D 4791 – Percent Flat Particles, Elongated Particles or Flat & Elongated Particles in Coarse Aggregate
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Appendix C: Multi-Laboratory Precision

Test 1	2005		2006		2007		2008		ASTM C117
WP 75 μm	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	1.18	1.16	1.36	1.46	0.80	0.80	0.39	0.39	<1.5
1S	0.23	0.26	0.27	0.28	0.17	0.15	0.20	0.20	0.22
D2S	0.65	0.73	0.77	0.81	0.47	0.42	0.56	0.57	0.62
n/Outliers	192/12		200/8		199/6		210/3		

Test 2	2005		2006		2007		2008		ASTM C136[A]
P 19.0 mm	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	92.8	91.8	95.6	95.6	93.8	92.8	97.8	97.8	100 - 95
1S	1.1	1.1	0.8	0.7	1.4	1.7	0.5	0.6	0.35
D2S	3.1	3.2	2.4	2.1	4.0	4.9	1.4	1.6	1.0
n/Outliers	206/0		208/0		203/2		210/3		

Test 3	2005		2006		2007		2008		ASTM C136[A]
P 16.0 mm	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	84.6	82.9	88.2	88.1	77.7	74.6	91.1	90.7	95 - 85
1S	1.3	1.4	1.1	0.9	2.0	3.4	0.9	0.9	1.37
D2S	3.6	4.1	3.2	2.5	5.6	9.7	2.5	2.6	3.9
n/Outliers	204/2		200/8		203/2		208/5		

Test 4	2005		2006		2007		2008		ASTM C136[A]
P 13.2 mm	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	77.5	75.4	81.5	81.3	60.8	57.1	82.9	82.3	85 - 80
1S	1.4	1.5	1.3	1.0	2.4	4.1	1.1	1.3	1.92
D2S	4.1	4.1	3.6	2.8	6.8	11.6	3.2	3.7	5.4
n/Outliers	204/2		207/1		202/3		210/3		

Test 5	2005		2006		2007		2008		ASTM C136[A]
P 9.5 mm	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	66.2	63.8	70.5	70.5	33.3	30.9	69.0	68.1	80 - 60
1S	1.5	1.6	1.4	1.1	2.2	3.1	1.2	1.4	2.82
D2S	4.2	4.4	4.0	3.2	6.2	8.8	3.4	4.1	8.0
n/Outliers	204/2		205/3		200/5		210/3		

Test 6	2005		2006		2007		2008		ASTM C136[A]
P 4.75 mm	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	49.9	47.8	55.5	55.5	4.5	4.3	51.1	50.2	60 – 20
1S	1.4	1.6	1.3	1.0	0.6	0.7	1.2	1.4	1.97
D2S	3.9	4.4	3.6	2.8	1.7	1.9	3.4	4.1	5.6
n/Outliers	203/3		204/4		200/5		206/7		

Test 8	2005		2006		2007		2008		ASTM C131	
L. L. A	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	C of V	$\sigma^{\cdot}$
Mean	23.44	23.19	18.47	18.15	23.4	23.5	22.4	22.1	10-45	22.2
1S	1.08	1.41	1.51	1.94	0.71	1.12	1.27	1.11	4.5%	1.00
D2S	3.05	3.97	4.26	5.50	2.00	3.18	3.61	3.14	12.7%	2.83
n/Outliers	11/0		10/0		9/1		10/1			

A – AMRL reports percent passing inch series equivalent sieves.

$\sigma^{\cdot}$ - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 9	2005		2006		2007		2008		ASTM C127
RD (O.D.)	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	2.660	2.660	2.669	2.669	2.683	2.684	2.657	2.657	
1S	0.007	0.009	0.005	0.006	0.007	0.006	0.007	0.008	0.013
D2S	0.020	0.025	0.014	0.017	0.020	0.017	0.020	0.023	0.038
n/Outliers	92/5		91/10		90/6		94/3		

Test 10	2005		2006		2007		2008		ASTM C127-88
ABS	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	1.544	1.549	1.840	1.835	0.497	0.494	0.971	0.954	< 2%
1S	0.143	0.167	0.093	0.081	0.066	0.079	0.089	0.087	0.145
D2S	0.403	0.471	0.263	0.229	0.187	0.223	0.252	0.246	0.41
n/Outliers	93/4		92/9		95/1		95/2		

Test 11	2005		2006		2007		2008		ASTM C88	
$MgSO_4$	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	C of V	σ'
Mean	13.6	13.5	7.5	7.5	3.3	3.2	4.3	4.2	9-20%	4.2
1S	3.4	3.0	2.2	2.1	1.1	1.0	1.4	1.4	25%	1.1
D2S	9.5	8.4	6.4	5.9	3.1	2.8	4.0	4.0	71%	3.0
n/Outliers	31/1		36/1		36/1		36/0			

Test 12	2005		2006		2007		2008		MTO Workshop
% Crush	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	68.7	69.1	74.3	74.2	65.2	66.8	63.1	63.6	50 - 75
1S	5.3	5.6	4.2	4.3	6.4	6.2	3.8	3.7	6.0%
D2S	14.8	15.8	11.8	12.3	18.1	17.7	10.8	10.5	16.9%
n/Outliers	201/3		196/12		201/4		202/11		

Test 13	2005		2006		2007		2008		MTO LS-608	
% F & E	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	C of V	σ'
Mean	6.5	6.2	9.7	8.9	15.3	15.5	3.3	3.5		3.4
1S	3.0	2.7	3.4	3.5	4.4	4.3	1.6	1.8	41%	1.4
D2S	8.5	7.8	9.7	10.0	12.4	12.2	4.5	5.1	116%	3.9
n/Outliers	162/6		163/6		164/2		170/6			

Test 14	2005		2006		2007		2008		ASTM
PN Conc.	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	
Mean	Analysis		122.7	120.9	113.6	112.7	113.4	115.8	No ASTM
1S	Not		7.9	7.7	5.7	6.7	5.4	8.0	Standard for this
D2S	Done		22.3	21.8	16.0	19.1	15.3	22.6	Test.
n/Outliers			25/0		23/1		25/3		

Test 16	2005		2006		2007		2008		MTO LS-618	
MDA, CA	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	C of V	σ'
Mean	11.49	11.43	5.6	5.4	12.2	12.4	14.7	14.7	5-20%	14.7
1S	0.61	0.72	0.38	0.35	0.70	0.66	0.77	0.85	5.6%	0.82
D2S	1.73	2.04	1.08	0.98	1.99	1.88	2.17	2.41	15.8%	2.33
n/Outliers	61/4		58/3		60/3		65/4			

Test 17	2005		2006		2007		2008		MTO LS-614	
Freeze-thaw	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	C of V	σ'
Mean	14.59	14.77	12.68	13.22	4.53	4.28	7.62	7.68	5-18%	7.65
1S	2.95	3.16	1.38	2.00	1.00	0.85	1.59	1.67	21%	1.61
D2S	8.31	8.92	3.91	5.67	2.82	2.40	4.51	4.74	59%	4.55
n/Outliers	47/3		44/4		46/3		49/2			

A – AMRL reports percent passing inch series equivalent sieves.

σ' - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 20 P 2.36 mm	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C136[A]
Mean	37.4	36.2	45.4	45.3	92.9	93.0	40.9	40.4	60 - 20
1S	1.7	1.8	1.7	1.6	0.9	0.7	1.7	1.6	1.41
D2S	4.9	5.0	4.8	4.5	2.6	1.9	4.7	4.6	4.0
n/Outliers	205/1		202/6		201/4		207/6		

Test 21 P 1.18 mm	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C136[A]
Mean	25.7	25.0	36.5	36.5	68.1	68.4	33.3	32.9	60 - 20
1S	1.5	1.7	2.1	1.9	1.9	1.7	1.8	1.8	1.41
D2S	4.3	4.9	5.9	5.5	5.5	4.7	5.1	5.1	4.0
n/Outliers	205/1		206/2		202/3		210/3		

Test 22 P 600 μm	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C136[A]
Mean	17.0	16.6	28.2	28.2	33.2	33.5	26.5	26.3	60 - 20
1S	1.1	1.3	1.8	1.9	2.1	1.9	1.6	1.6	1.41
D2S	3.2	3.7	5.2	5.3	6.0	5.4	4.7	4.6	4.0
n/Outliers	204/2		207/1		203/2		209/4		

Test 23 P 300 μm	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C136[A]
Mean	11.9	11.6	19.0	19.1	9.5	9.4	18.4	18.2	20 - 15
1S	0.8	0.9	1.3	1.4	1.1	0.7	1.1	1.1	1.10
D2S	2.4	2.7	3.6	3.9	3.2	2.1	3.1	3.2	3.1
n/Outliers	204/2		207/1		197/8		206/7		

Test 24 P 150 μm	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C136[A]
Mean	9.4	9.2	12.0	12.2	2.7	2.6	12.0	12.0	15 - 10
1S	0.7	0.7	0.8	0.8	0.4	0.4	0.7	0.7	0.73
D2S	1.9	1.9	2.3	2.4	1.2	1.0	1.9	2.0	2.1
n/Outliers	202/4		205/3		202/3		206/7		

Test 25 P 75 μm	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C136[A]
Mean	7.8	7.6	7.7	7.8	1.7	1.6	8.2	8.2	10 - 2
1S	0.6	0.6	0.6	0.6	0.3	0.3	0.5	0.5	0.65
D2S	1.7	1.7	1.6	1.6	0.9	0.9	1.4	1.5	1.8
n/Outliers	203/3		202/6		199/6		205/8		

Test 27 RD (O.D.)	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C128
Mean	2.593	2.501	2.665	2.615	2.611	2.601	2.659	2.660	
1S	0.017	0.045	0.015	0.038	0.011	0.013	0.011	0.009	0.023
D2S	0.048	0.127	0.042	0.107	0.031	0.037	0.031	0.025	0.066
n/Outliers	87/8		90/10		83/10		89/5		

Test 28 ABS	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C128
Mean	1.713	3.109	0.746	1.502	1.849	1.993	0.644	0.642	< 1.0%
1S	0.30	0.78	0.13	0.49	0.16	0.14	0.11	0.12	0.23
D2S	0.86	2.20	0.37	1.38	0.46	0.39	0.32	0.34	0.66
n/Outliers	91/4		88/12		80/13		91/3		

A – AMRL reports percent passing inch series equivalent sieves.

σ' - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 29	2005		2006		2007		2008		ASTM C88
$MgSO_4$	3.05	4.05	3.06	4.06	1.07	2.07	1.08	2.08	
Mean	17.3	17.0	11.7	11.7	14.8	15.3	This Test is		ASTM precision
1S	3.6	3.9	3.4	3.2	4.7	4.3	Discontinued		Statements for
D2S	10.0	10.9	9.6	9.0	13.2	12.2	from the		Coarse
n/Outliers	29/2		31/0		32/0		Program		Aggregate only

Test 30	2005		2006		2007		2008		MTO LS-621	
% ACP	1.05	2.05	1.06	2.06	1.07	2.07	1.08	2.08	C of V	σ
Mean	39.4	40.1	39.7	39.9	29.5	29.4	36.5	37.1	25-45%	36.8
1S	3.6	3.1	4.7	4.7	4.8	4.7	5.9	6.0	9.6%	3.5
D2S	10.2	8.8	13.2	13.3	13.7	13.3	16.8	17.00	27.0%	10.0
n/Outliers	188/14		206/1		203/1		210/3			

Test 31	2005		2006		2007		2008		MTO LS-623
MWD	3.05	4.05	3.06	4.06	1.07	2.07	1.08	2.08	
Mean	2.308	2.306	2.271	2.272	2.382	2.385	2.320	2.317	
1S	0.037	0.040	0.031	0.030	0.039	0.032	0.039	0.046	0.030
D2S	0.104	0.112	0.088	0.085	0.110	0.090	0.110	0.130	0.085
n/Outliers	143/4		147/4		145/2		151/1		

Test 32	2005		2006		2007		2008		MTO LS-623
MDD	3.05	4.05	3.06	4.06	1.07	2.07	1.08	2.08	
Mean	2.134	2.133	2.093	2.095	2.223	2.226	2.151	2.151	
1S	0.045	0.051	0.038	0.041	0.035	0.034	0.041	0.047	0.033
D2S	0.127	0.144	0.107	0.116	0.099	0.096	0.116	0.133	0.093
n/Outliers	147/0		149/2		147/0		151/1		

Test 33	2005		2006		2007		2008		MTO LS-623
OMC	3.05	4.05	3.06	4.06	1.07	2.07	1.08	2.08	
Mean	8.16	8.20	8.55	8.48	7.37	7.34	7.95	7.93	
1S	0.47	0.52	0.50	0.61	0.32	0.32	0.45	0.39	0.41
D2S	1.33	1.46	1.41	1.72	0.90	0.90	1.27	1.12	1.15
n/Outliers	144/3		147/4		144/3		146/6		

Test 34	2005		2006		2007		2008		MTO LS-619	
MDA, FA3	3.05	4.05	3.06	4.06	1.07	2.07	1.08	2.08	C of V	σ
Mean	15.3	15.4	11.6	11.7	16.8	16.7	11.9	11.8	7-30%	11.8
1S	1.1	1.1	0.9	0.8	1.1	0.8	0.9	0.8	8.7%	1.0
D2S	2.3	3.1	2.7	2.4	3.1	2.4	2.5	2.2	24.6%	2.9
n/Outliers	62/3		60/2		58/5		63/6			

Test 40	2005		2006		2007		2008		MTO LS-702
P 2.0 mm	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	99.9	99.9	100.0	99.9	99.9	99.9	100.0	100.0	No MTO
1S									precision
D2S									statements for
n/Outliers	67/0		68/0		66/0		70/0		this test

Test 41	2005		2006		2007		2008		MTO LS-702
P 425 µm	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	96.5	96.5	96.9	96.9	97.0	97.1	99.8	99.8	No MTO
1S	0.3	0.4	0.5	0.5	0.6	0.5	0.1	0.1	precision
D2S	1.0	1.1	1.6	1.4	1.6	1.5	0.4	0.4	statements for
n/Outliers	59/8		61/7		61/5		66/4		this test

A – AMRL reports percent passing inch series equivalent sieves.

σ' - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 42	2005		2006		2007		2008		MTO LS-702
P 75 µm	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	88.7	88.8	91.7	91.5	91.6	91.7	99.1	99.1	No MTO
1S	0.6	0.5	0.8	0.8	0.8	0.8	0.3	0.3	precision
D2S	1.6	1.5	2.3	2.2	2.3	2.2	1.0	1.0	statements for
n/Outliers	63/4		60/8		62/4		66/4		this test

Test 43	2005		2006		2007		2008		MTO LS-702
P 20 µm	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	71.0	70.3	78.1	78.9	78.7	78.7	80.4	80.1	No MTO
1S	4.8	4.1	6.0	4.5	3.5	4.1	4.6	4.5	precision
D2S	13.6	11.6	17.1	12.8	9.8	11.5	12.9	12.7	statements for
n/Outliers	65/2		61/7		63/3		69/1		this test

Test 44	2005		2006		2007		2008		MTO LS-702
P 5 µm	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	44.0	43.8	59.2	58.9	59.2	59.4	44.8	44.2	No MTO
1S	3.7	3.3	2.7	2.9	2.8	3.2	3.8	3.0	precision
D2S	10.6	9.3	7.8	8.1	8.0	9.1	10.8	8.6	statements for
n/Outliers	64/3		58/10		60/6		66/4		this test

Test 45	2005		2006		2007		2008		MTO LS-702
P 2 µm	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	30.5	30.5	44.4	44.6	44.0	44.6	29.9	29.4	No MTO
1S	3.1	3.0	3.1	3.1	3.4	3.3	3.3	3.2	precision
D2S	8.8	8.6	8.9	8.8	9.7	9.5	9.5	9.0	statements for
n/Outliers	65/2		61/7		63/3		67/3		this test

Test 46	2005		2006		2007		2008		ASTM D4318
L. L	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	27.7	27.6	37.1	36.9	37.0	37.2	32.6	32.7	33.3
1S	1.4	1.5	1.9	1.9	1.6	1.5	1.4	1.4	0.8
D2S	4.0	4.1	5.3	5.4	4.5	4.2	3.9	4.1	2
n/Outliers	73/4		77/1		76/3		77/3		

Test 47	2005		2006		2007		2008		ASTM D4318
P. L	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	15.6	15.5	19.2	19.0	18.9	19.1	19.0	18.9	19.9
1S	1.3	1.5	1.6	1.6	1.3	0.9	1.1	1.0	1.3
D2S	3.7	4.4	4.4	4.4	3.8	2.7	3.1	2.9	4
n/Outliers	75/2		74/4		77/2		76/4		

Test 48	2005		2006		2007		2008		ASTM D4318
P. I	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	12.3	12.3	17.9	18.0	18.1	18.1	13.8	13.8	13.4
1S	1.7	1.8	1.7	1.9	1.3	1.4	1.8	1.5	1.6
D2S	4.7	5.2	4.7	5.6	3.8	4.0	5.2	4.3	4
n/Outliers	77/0		75/3		70/9		75/5		

Test 49	2005		2006		2007		2008		AASHTO T 100
SG of Soils	5.05	6.05	5.06	6.06	5.07	6.07	5.08	6.08	
Mean	2.729	2.728	2.733	2.730	2.731	2.732	2.719	2.724	
1S	0.027	0.030	0.030	0.031	0.027	0.026	0.029	0.023	0.04
D2S	0.076	0.085	0.085	0.088	0.076	0.074	0.082	0.065	0.11
n/Outliers	52/6		52/4		44/11		54/4		

A – AMRL reports percent passing inch series equivalent sieves.

σ' - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 95 UC Void	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C1252
Mean	41.19	40.33	43.13	42.06	41.32	41.21	41.86	41.91	ASTM C1252[A]
1S	1.45	1.39	0.68	1.08	0.70	0.52	0.57	0.54	0.33%
D2S	4.08	3.91	1.93	3.06	1.97	1.48	1.63	1.52	0.93%
n/Outliers	50/1		50/5		54/3		52/6		

Test 96 SE Value	2005 3.05	4.05	2006 3.06	4.06	2007 1.07	2.07	2008 1.08	2.08	ASTM D2419
Mean	30.7	30.0	56.4	55.9	90.6	90.8	35.5	35.2	< 80
1S	3.74	2.82	5.76	5.91	3.49	3.75	4.01	3.95	8.0
D2S	10.54	7.95	16.30	16.72	9.89	10.63	11.34	11.19	22.6
n/Outliers	42/7		53/0		54/0		56/0		

Test 97 % Fractured	2005 1.05	2.05	2006 1.06	2.06	2007 1.07	2.07	2008 1.08	2.08	ASTM D5821
Mean	71.28	70.54	75.7	76.1	67.0	67.8	63.6	64.4	76.0%
1S	5.02	5.24	3.9	4.7	3.7	4.6	3.9	3.7	5.2%
D2S	14.17	14.77	11.21	13.31	10.4	12.9	11.1	10.5	14.7%
n/Outliers	53/0		54/3		54/4		58/2		

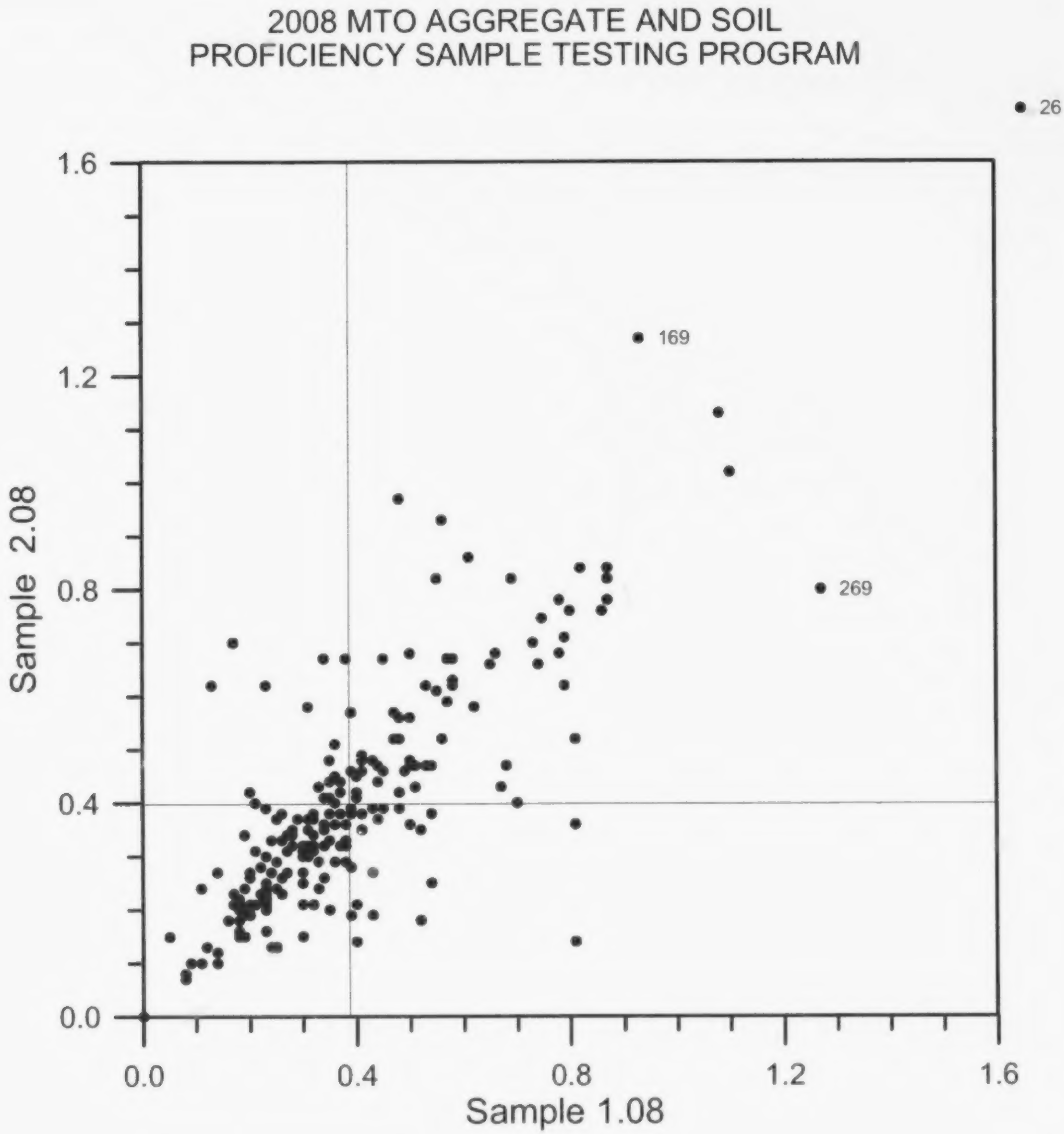
Test 99 % F & E	2005 1.05	2.05	2006 1.06	2.06	2007 1.07	2.07	2008 1.08	2.08	ASTM D4791
Mean	1.14	1.18	2.68	2.25	4.42	4.53	0.48	0.56	No ASTM
1S	0.69	0.67	1.36	1.16	1.86	1.99	0.35	0.31	precision
D2S	1.94	1.89	3.86	3.27	5.27	5.63	1.00	0.89	statements for
n/Outliers	46/7		55/1		55/2		56/4		this test

Test 123 Mortar Bar	2005 1.05	2.05	2006 1.06	2.06	2007 1.07	2.07	2008 1.08	2.08	ASTM C1260
Mean	Not Conducted		Not Conducted		Not Conducted		Not Conducted		Expansion >0.1%
1S									15.2%
D2S									43 %
n/Outliers									

A – AMRL reports percent passing inch series equivalent sieves.

σ - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Appendix D1: Scatter Diagrams



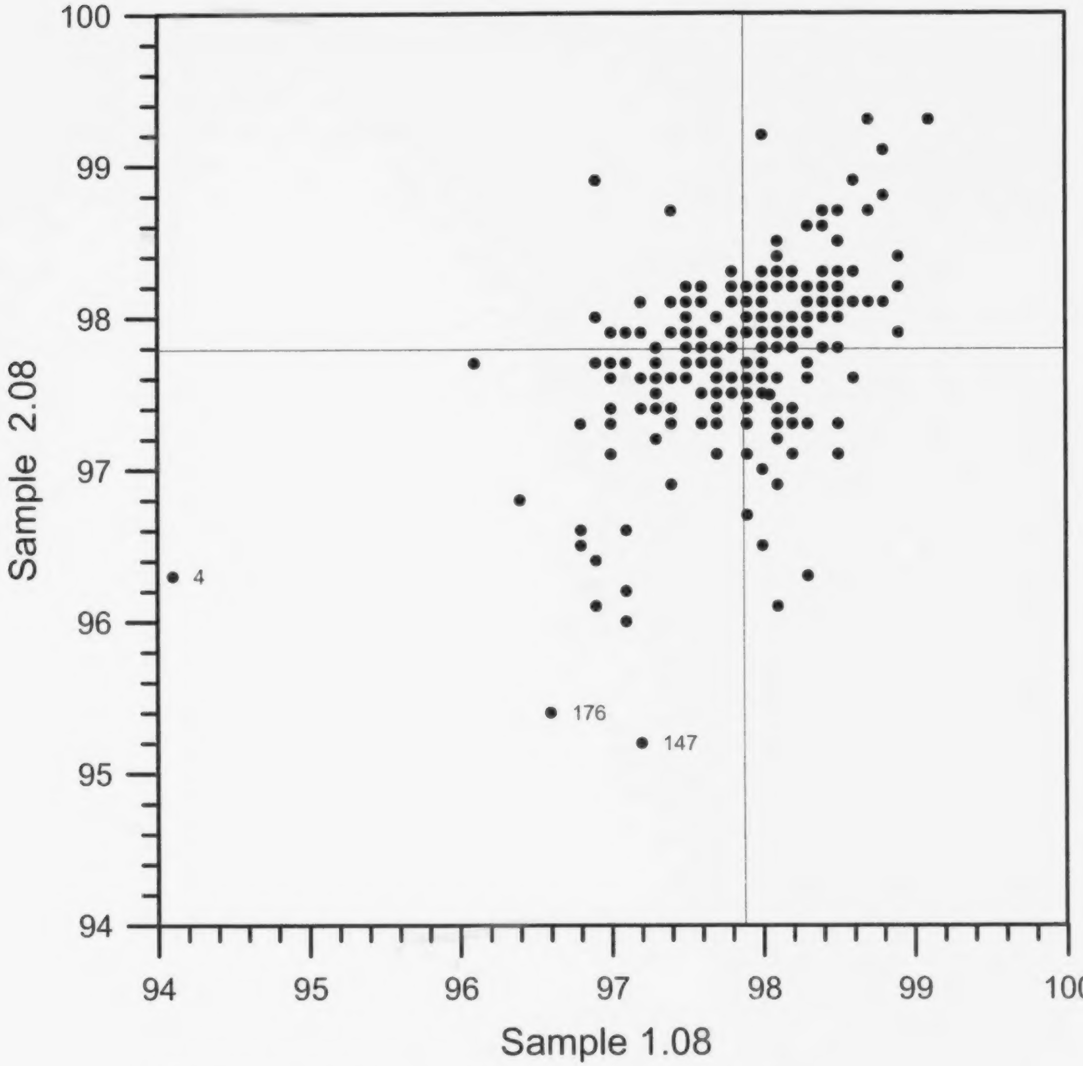
Test 1: Wash Pass 75 um

	Mat 1	Mat 2
Mean	0.386	0.393
Median	0.550	0.565
Std Dev	0.198	0.201

n = 210

Labs Eliminated: 26; 169; 269

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



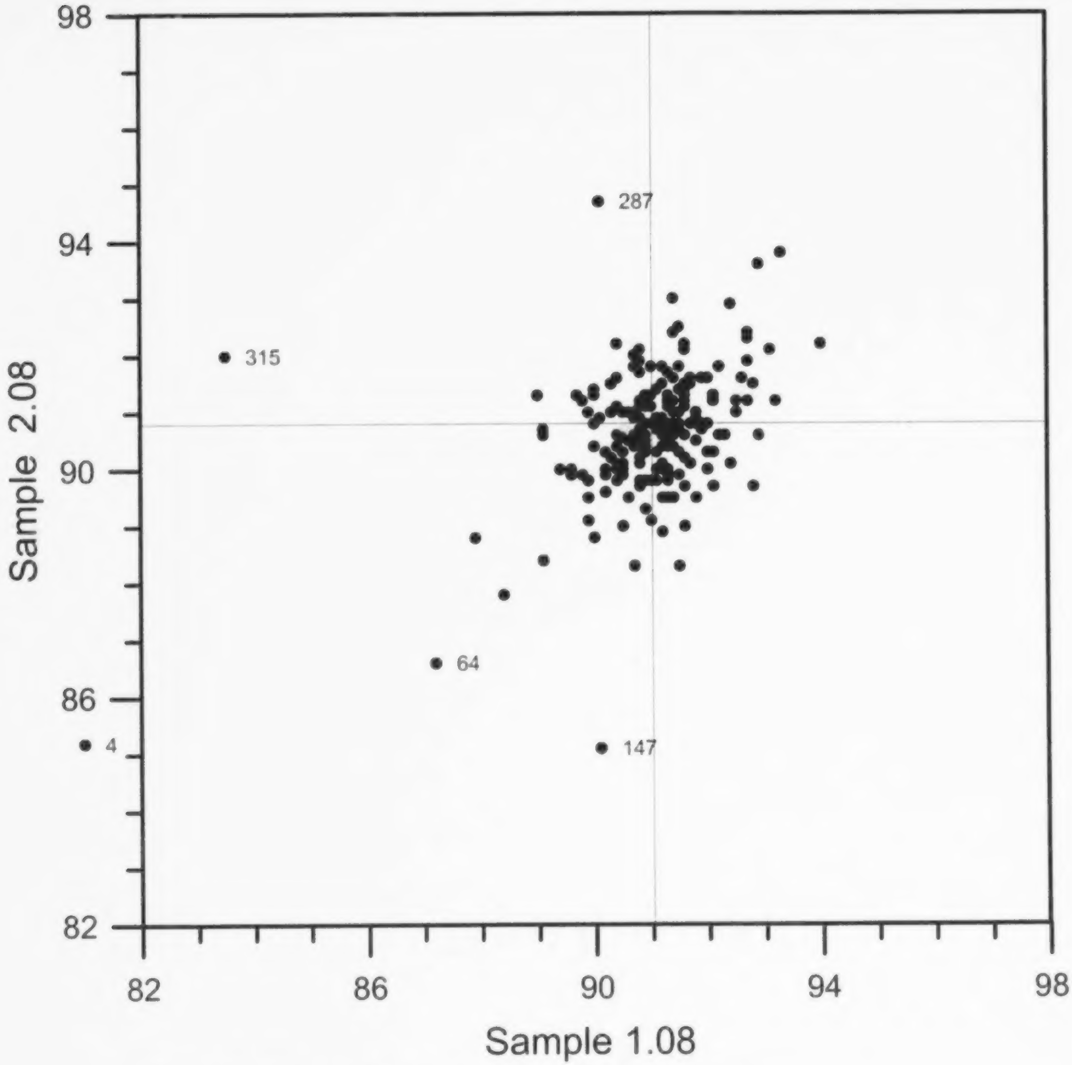
Test 2: Percent Passing the 19.0 mm Sieve

	Mat 1	Mat 2
Mean	97.867	97.793
Median	97.600	97.650
Std Dev	0.515	0.557

n = 210

Lab Eliminated: 4; 147; 176

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



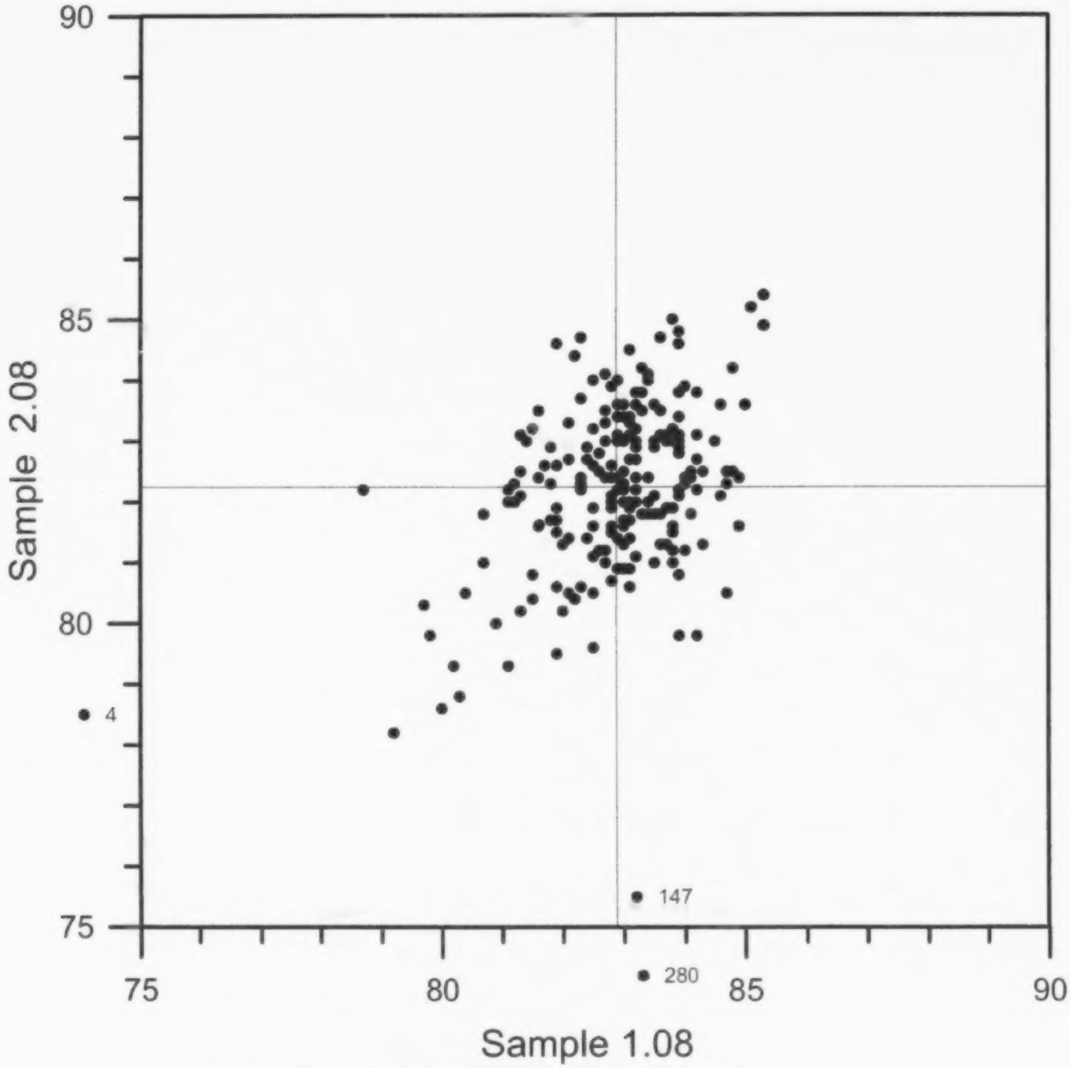
Test 3: Percent Passing the 16.0 mm Sieve

	Mat 1	Mat 2
Mean	91.083	90.722
Median	90.950	90.800
Std Dev	0.869	0.919

n = 208

Lab Eliminated: 4; 64; 147; 287; 315

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



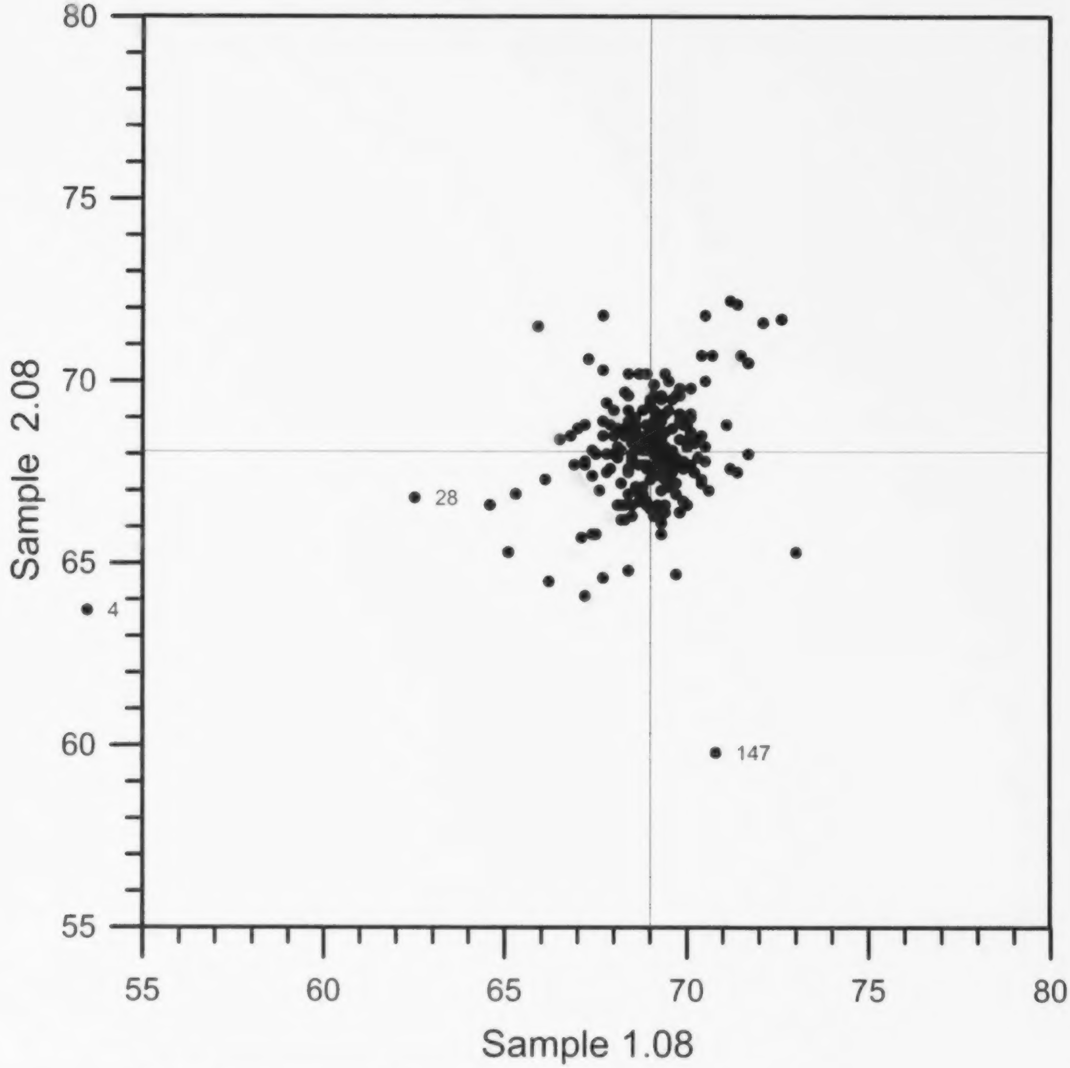
Test 4: Percent Passing the 13.20 mm Sieve

	Mat 1	Mat 2
Mean	82.913	82.277
Median	82.000	81.800
Std Dev	1.125	1.310

n = 210

Lab Eliminated: 4; 147; 280

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



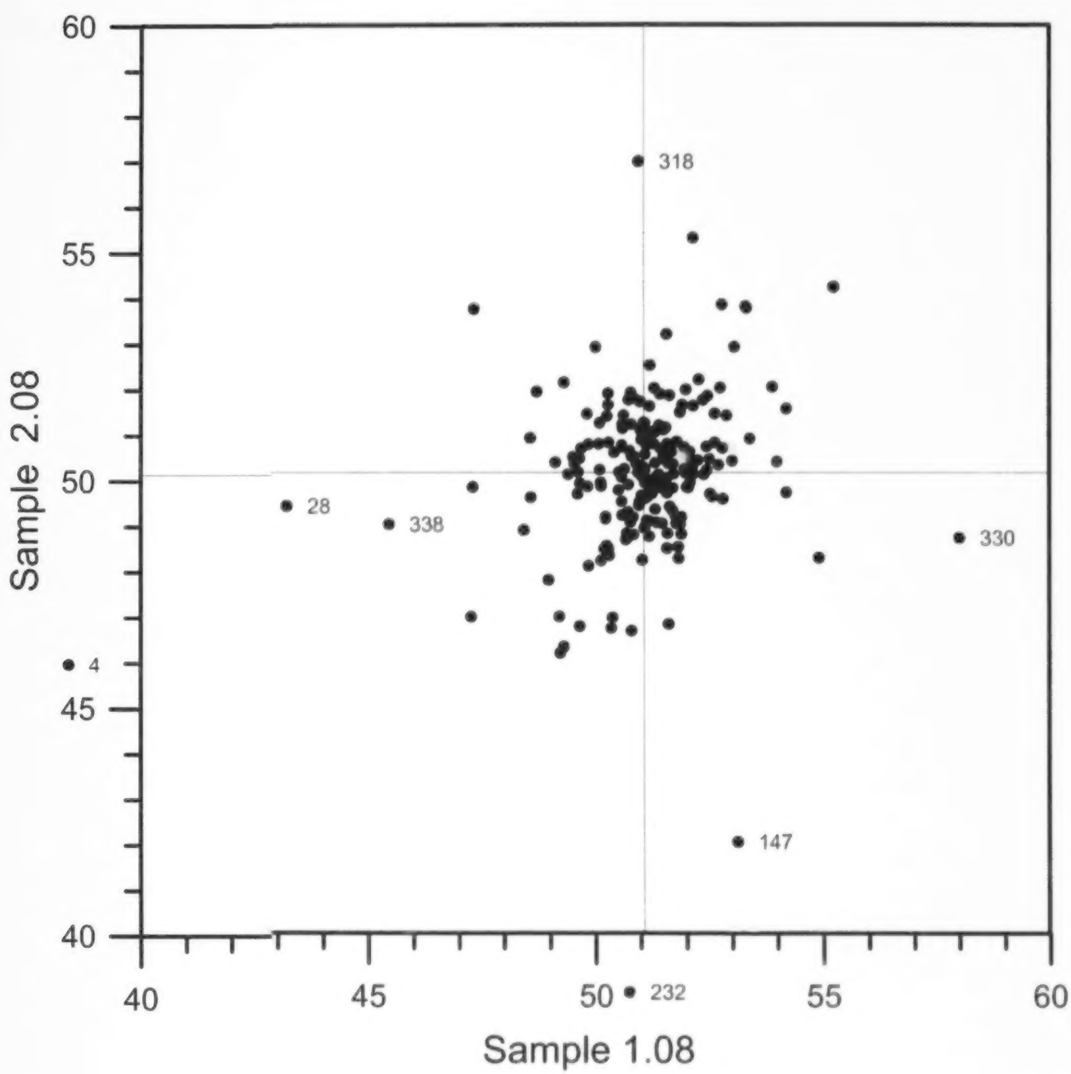
Test 5: Percent Passing the 9.5 mm Sieve

	Mat 1	Mat 2
Mean	69.022	68.092
Median	68.800	68.150
Std Dev	1.212	1.435

n = 210

Labs Eliminated: 4; 28; 147

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



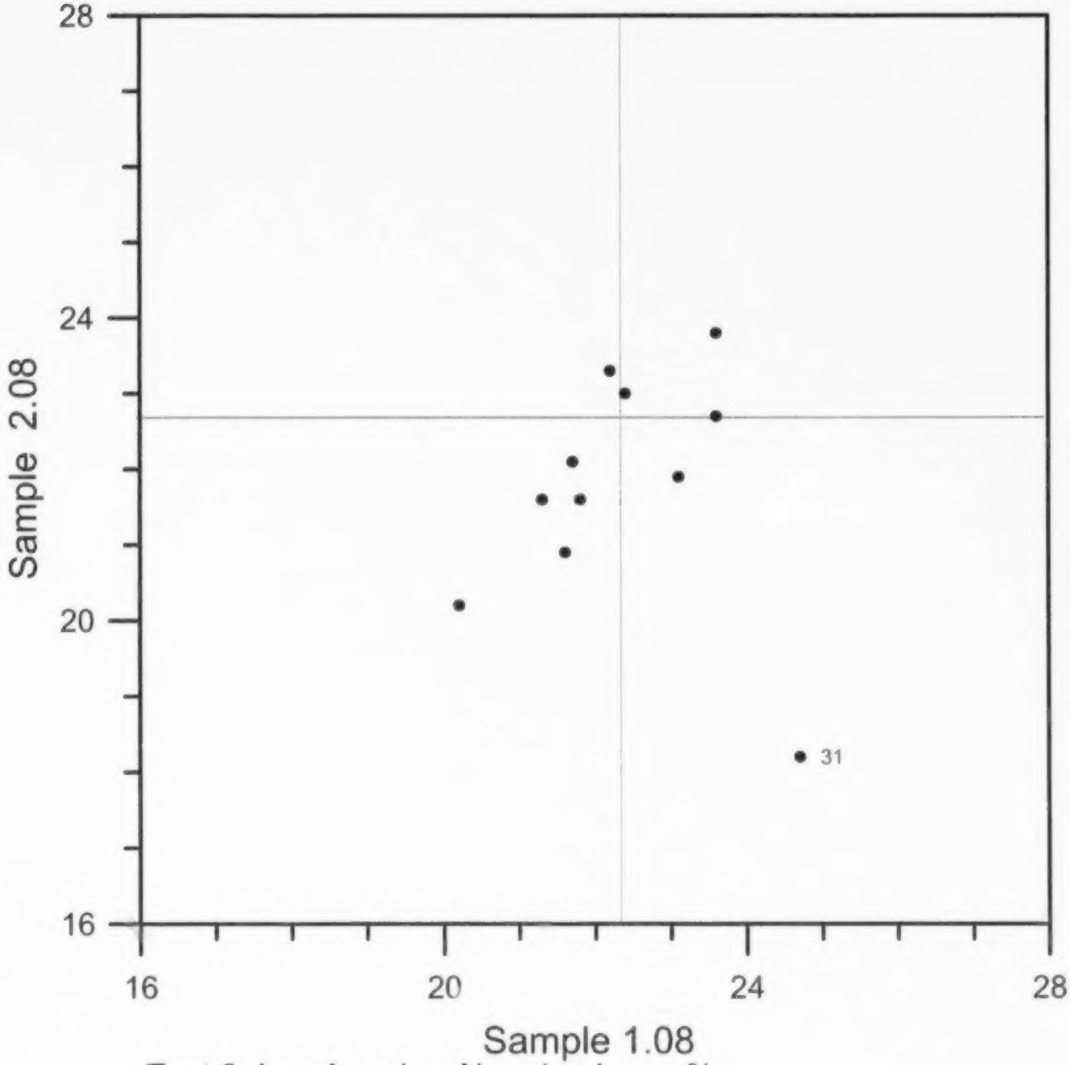
Test 6: Percent Passing the 4.75 mm Sieve

	Mat 1	Mat 2
Mean	51.153	50.181
Median	51.250	50.735
Std Dev	1.194	1.447

n = 206

Lab Eliminated: 4; 28; 147; 232; 318; 330; 338

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



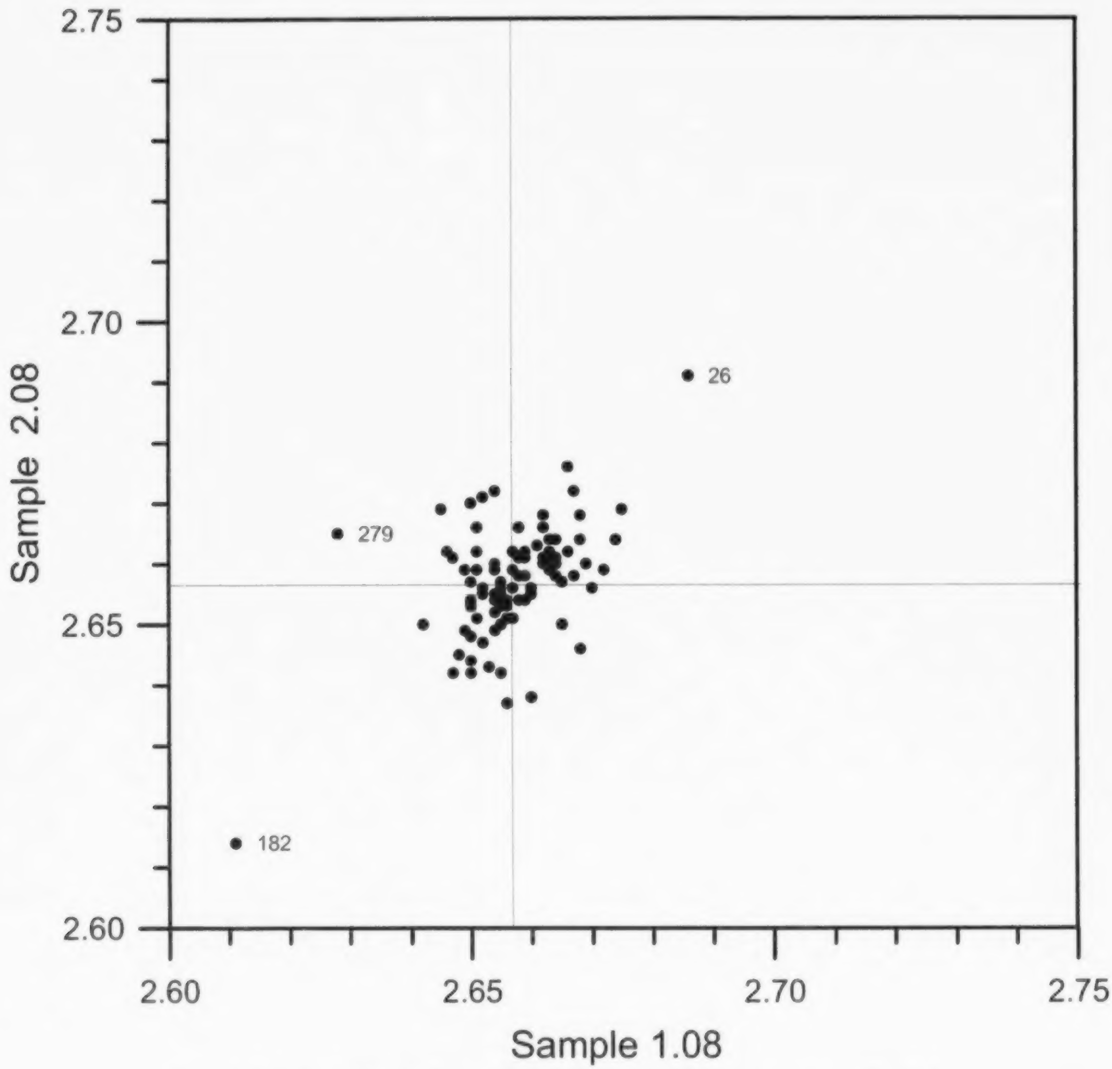
Test 8: Los Angeles Abrasion Loss, %

	Mat 1	Mat 2
Mean	22.382	22.110
Median	21.900	22.000
Std Dev	1.274	1.110

n = 10

Labs Eliminated: 31

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



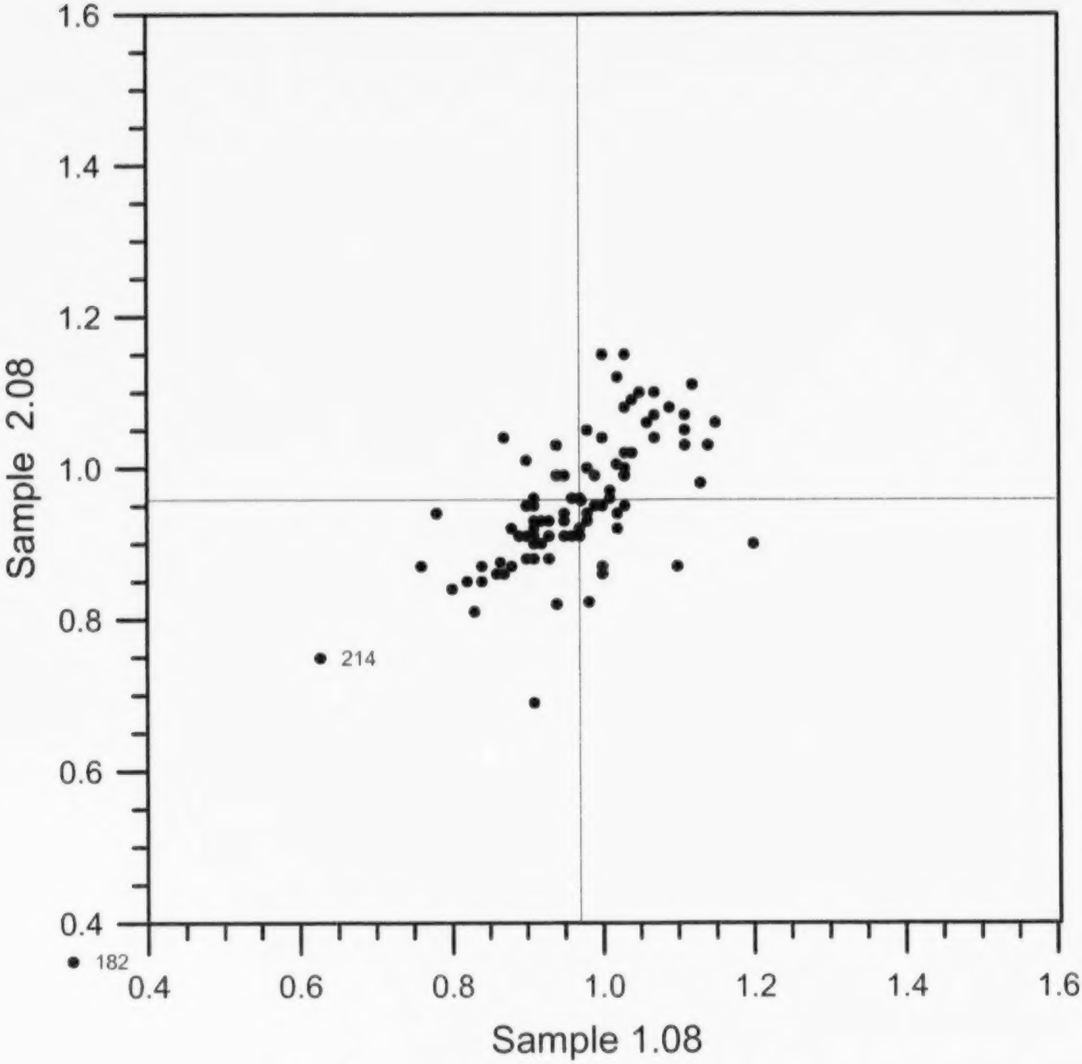
Test 9: Relative Density, (Coarse Aggregate - Bulk)

	Mat 1	Mat 2
Mean	2.657	2.657
Median	2.659	2.657
Std Dev	0.007	0.008

n = 94

Labs Eliminated: 26; 182; 279

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



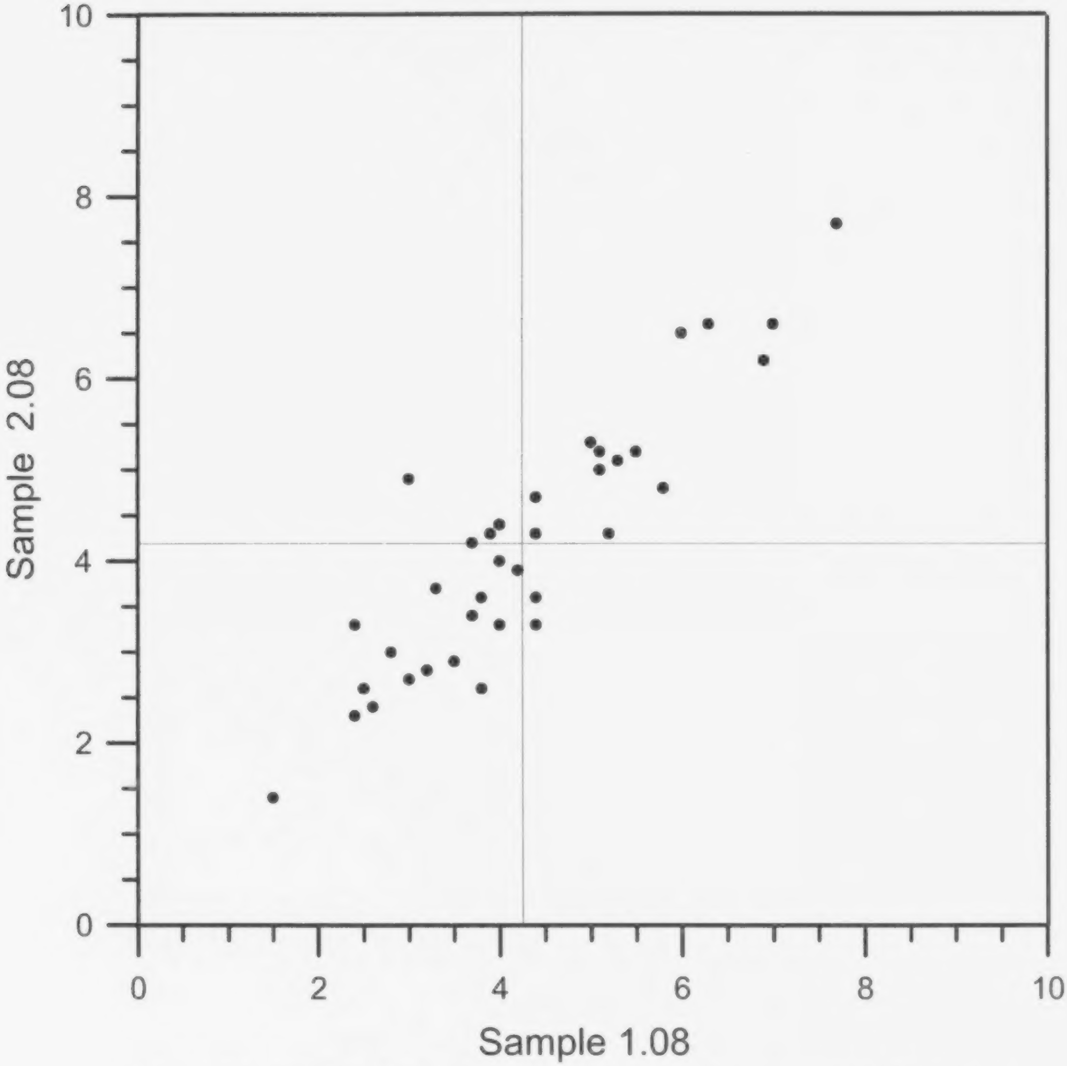
Test 10: Absorption (Coarse Aggregate)

	Mat 1	Mat 2
Mean	0.971	0.954
Median	0.980	0.920
Std Dev	0.089	0.087

n = 95

Labs Eliminated: 182; 214

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



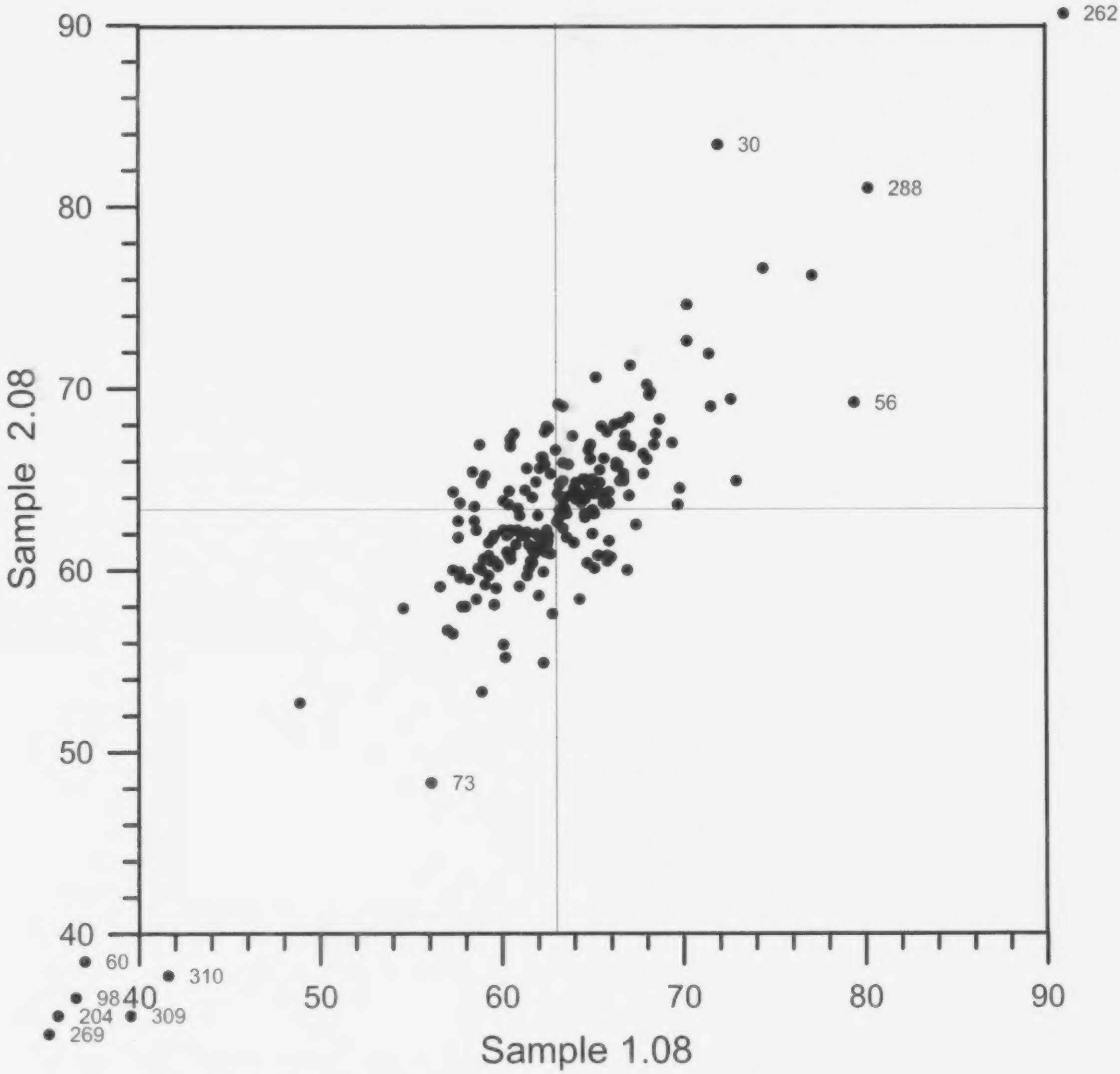
Test 11: MgSO4 Soundness (Coarse Aggregate), % Loss

	Mat 1	Mat 2
Mean	4.272	4.169
Median	4.600	4.550
Std Dev	1.425	1.416

n = 36

Lab Eliminated: None

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



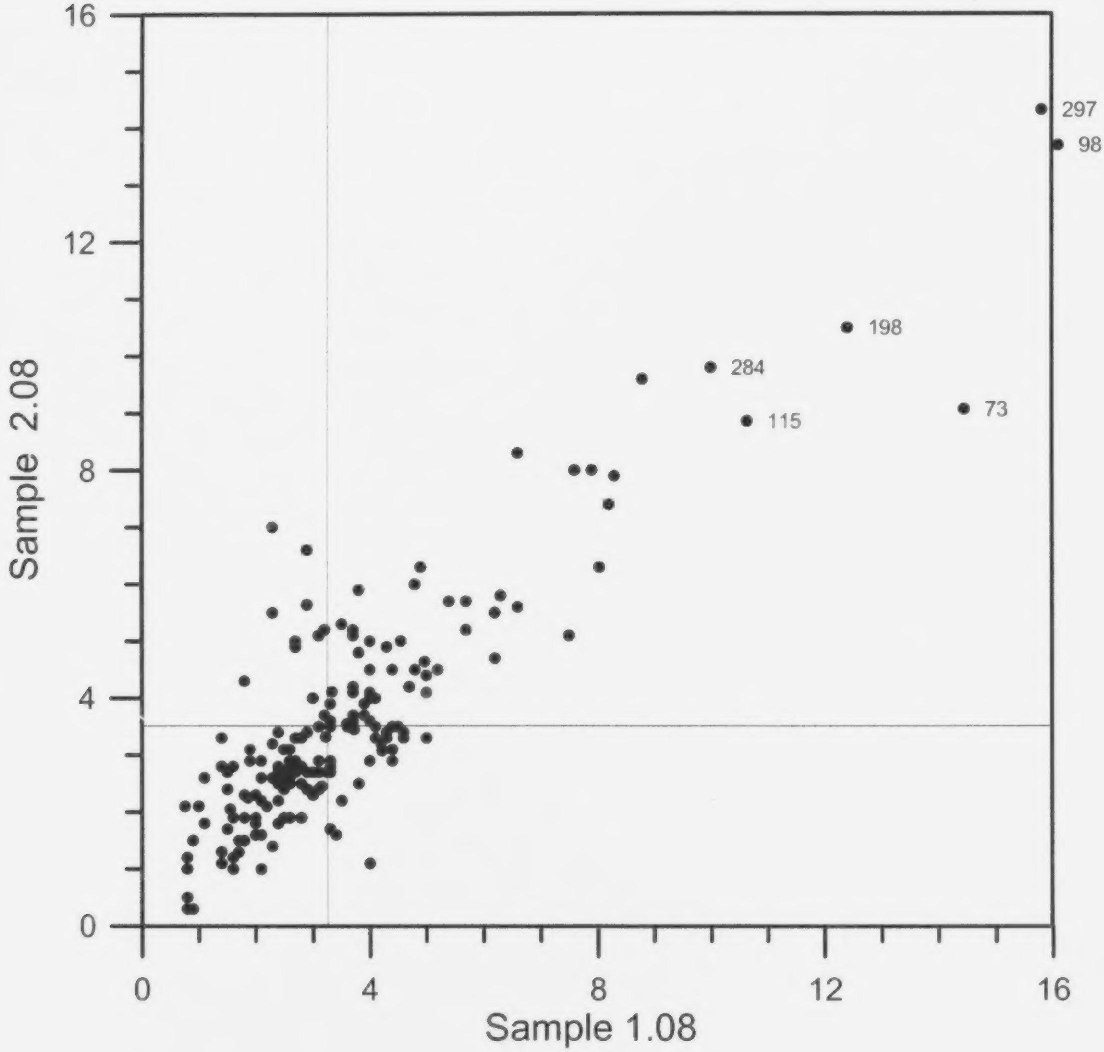
Test 12: Percent Crushed Particles

	Mat 1	Mat 2
Mean	63.138	63.558
Median	63.000	64.650
Std Dev	3.807	3.723

n = 202

Labs Eliminated: 30; 56; 60; 73; 98; 204; 262; 269; 288; 309; 310

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



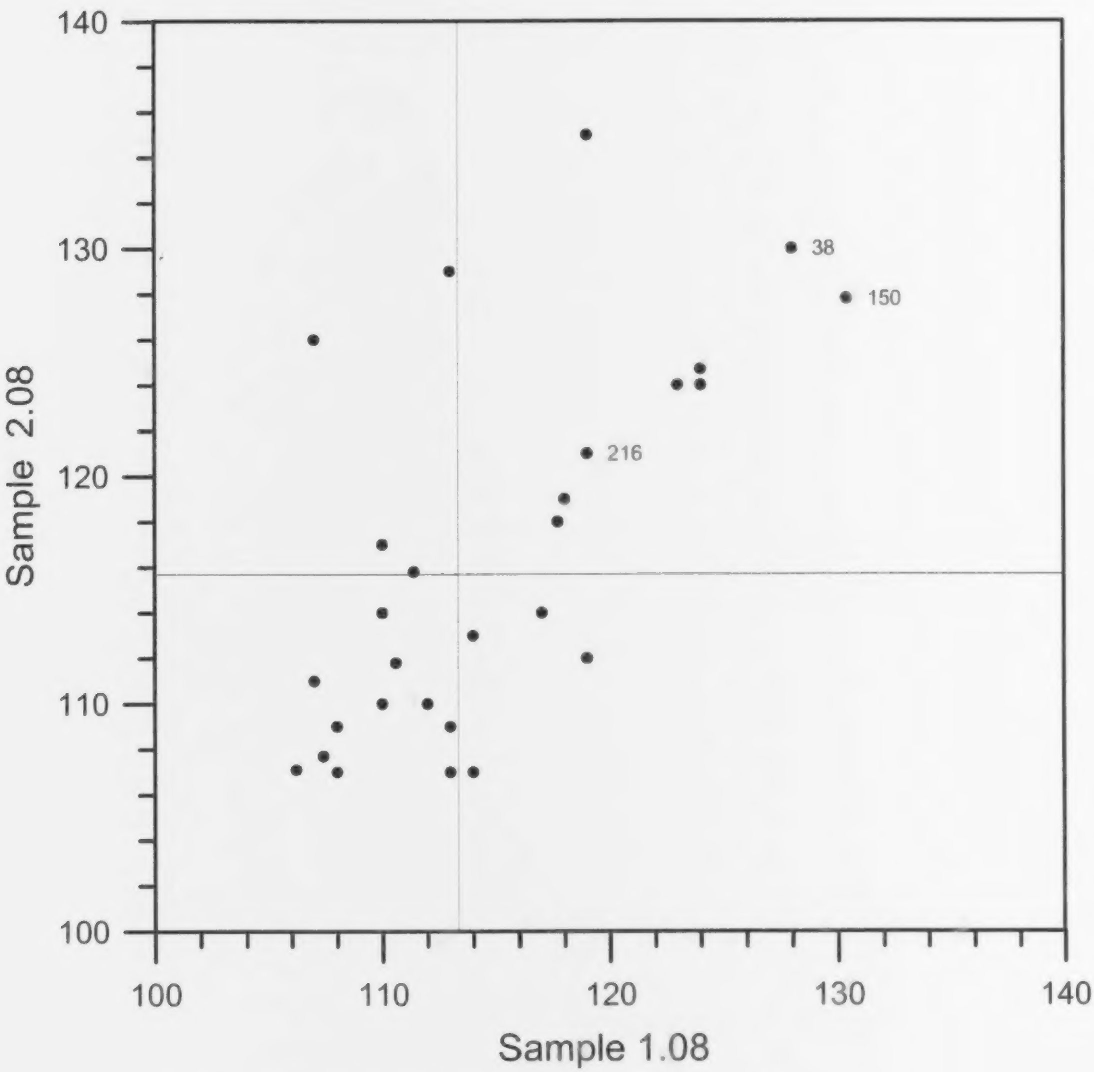
Test 13: Percent Flat and Elongated Particles

	Mat 1	Mat 2
Mean	3.271	3.476
Median	4.780	4.950
Std Dev	1.589	1.787

n = 170

Labs Eliminated: 73; 98; 115; 198; 284; 297

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



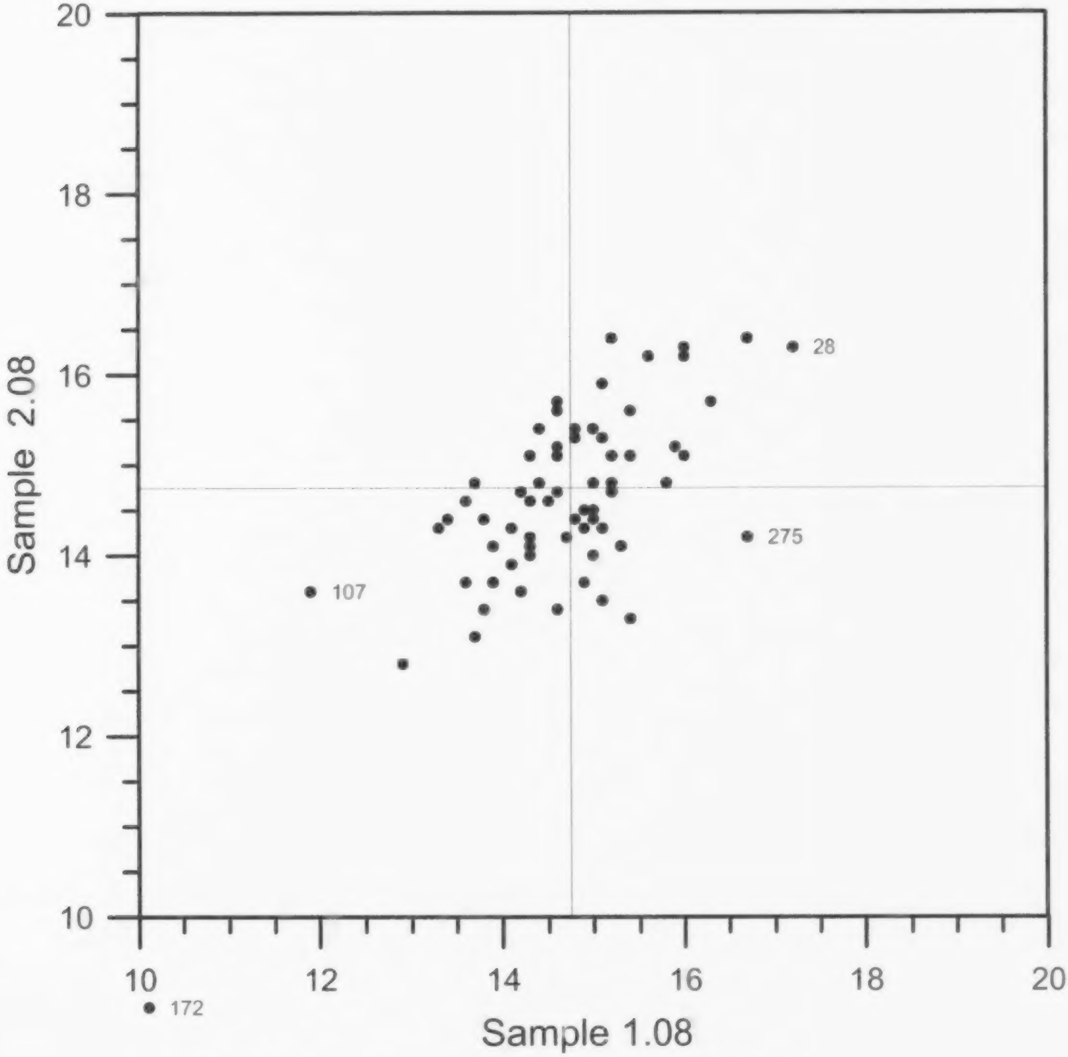
Test 14: Petrographic Number (Concrete)

	Mat 1	Mat 2
Mean	113.4	115.8
Median	115.1	121.0
Std Dev	5.4	8.0

n = 25

Lab Eliminated: 38; 150; 216

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



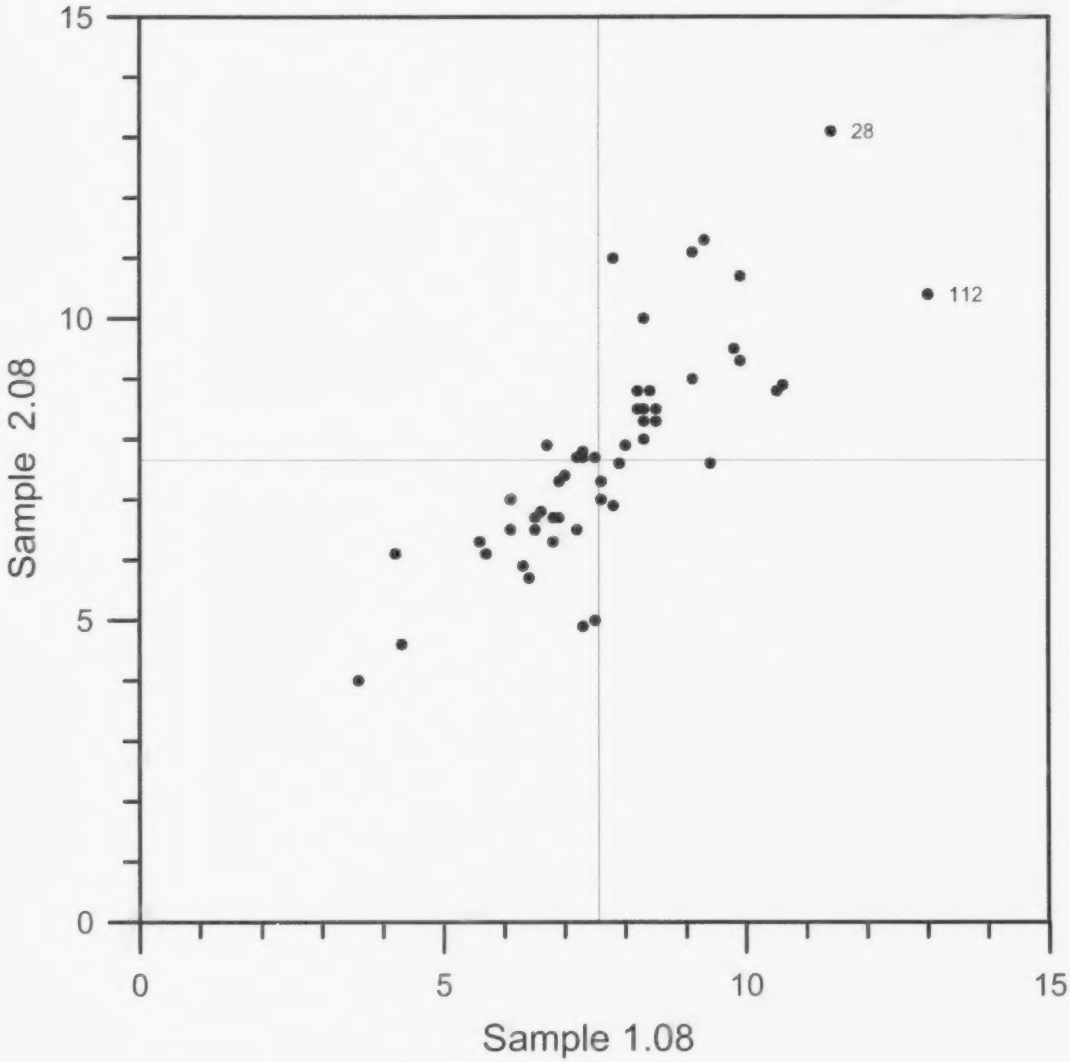
Test 16: Micro-Deval Abrasion Loss (CA), %

	Mat 1	Mat 2
Mean	14.752	14.707
Median	14.800	14.600
Std Dev	0.768	0.850

n = 65

Labs eliminated: 28; 107;172; 275

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



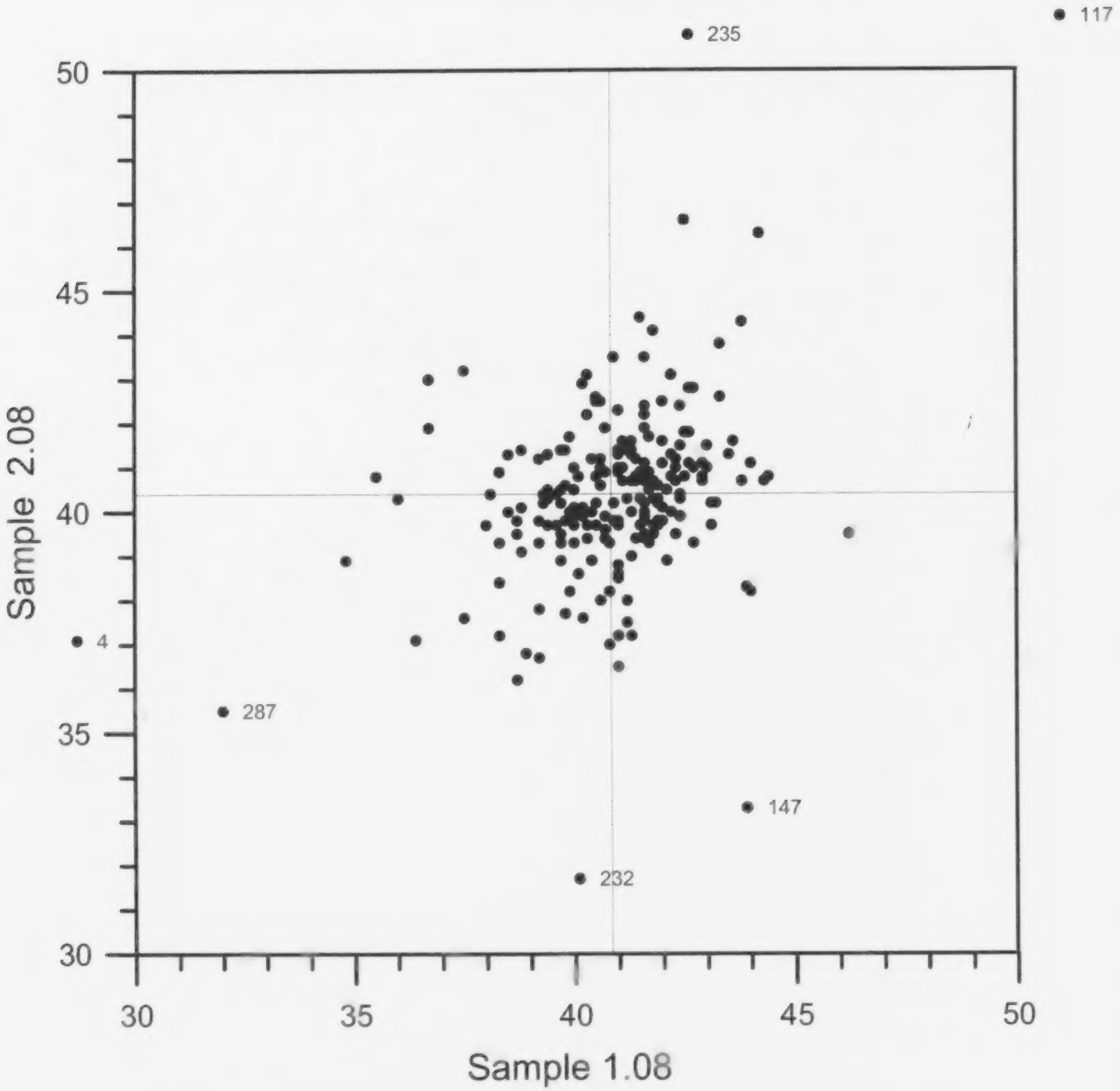
Test 17: Freeze-Thaw Loss, %

	Mat 1	Mat 2
Mean	7.620	7.676
Median	7.100	7.650
Std Dev	1.593	1.674

n = 49

Lab eliminated: 28; 112

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



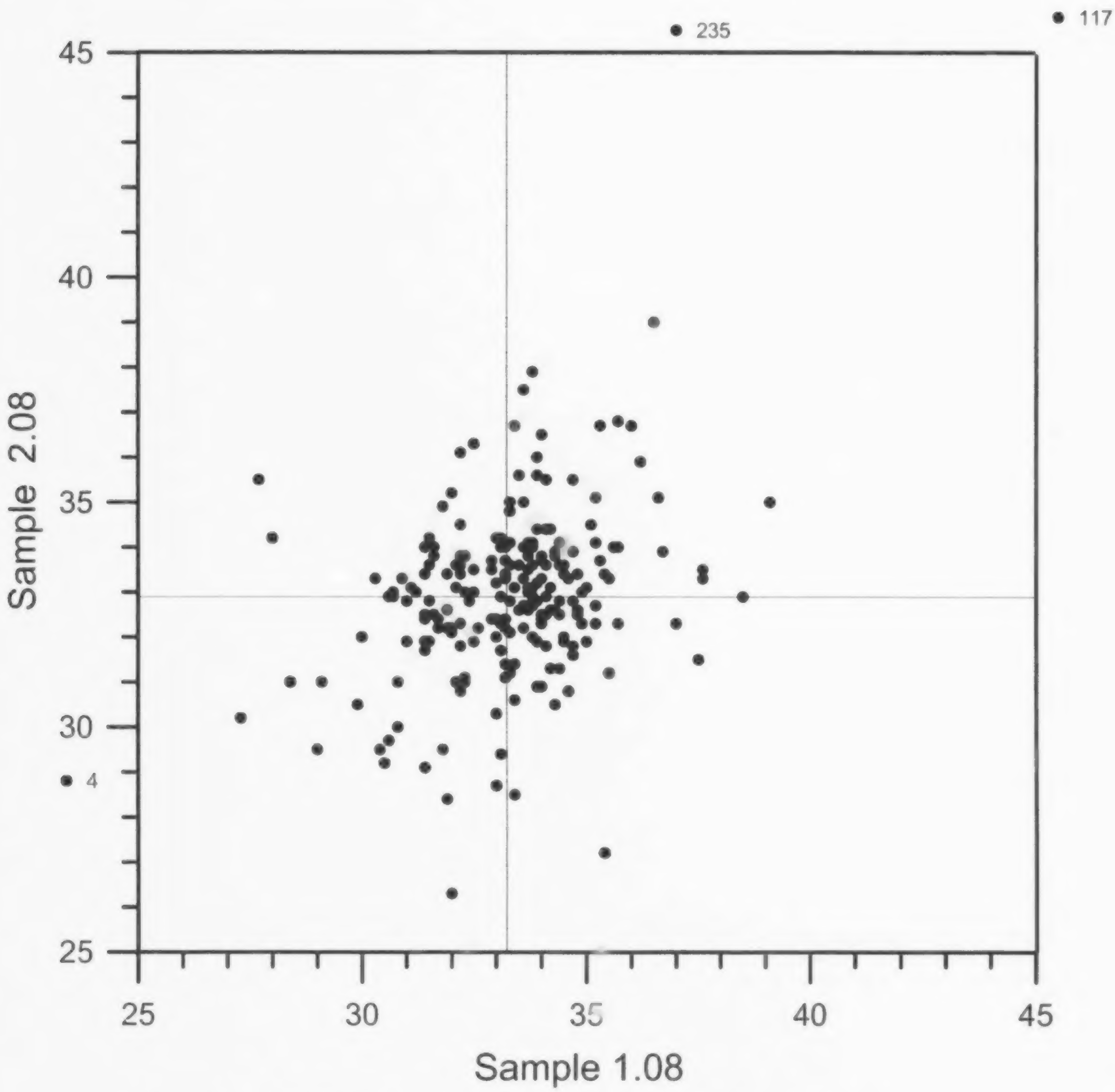
Test 20: Percent Passing the 2.36 mm Sieve

	Mat 1	Mat 2
Mean	40.950	40.401
Median	40.500	41.400
Std Dev	1.678	1.642

n = 207

Labs Eliminated: 4; 117; 147; 232; 235; 287

2008 MTO AGGREGATE AND SOIL
PROFICIENCY SAMPLE TESTING PROGRAM



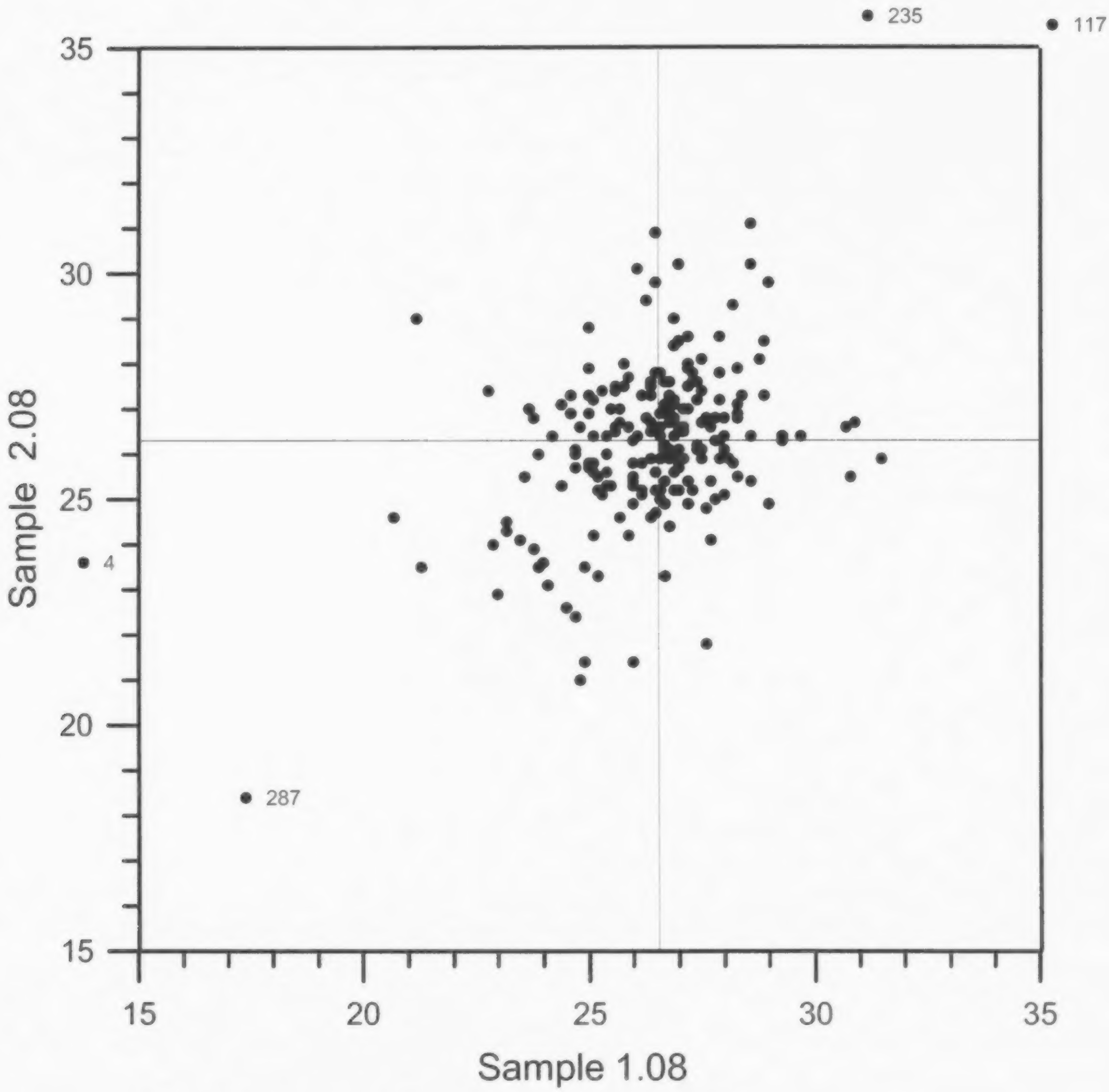
Test 21: Percent Passing the 1.18 mm Sieve

	Mat 1	Mat 2
Mean	33.307	32.890
Median	33.200	32.650
Std Dev	1.808	1.795

n = 210

Labs Eliminated: 4; 117; 235

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



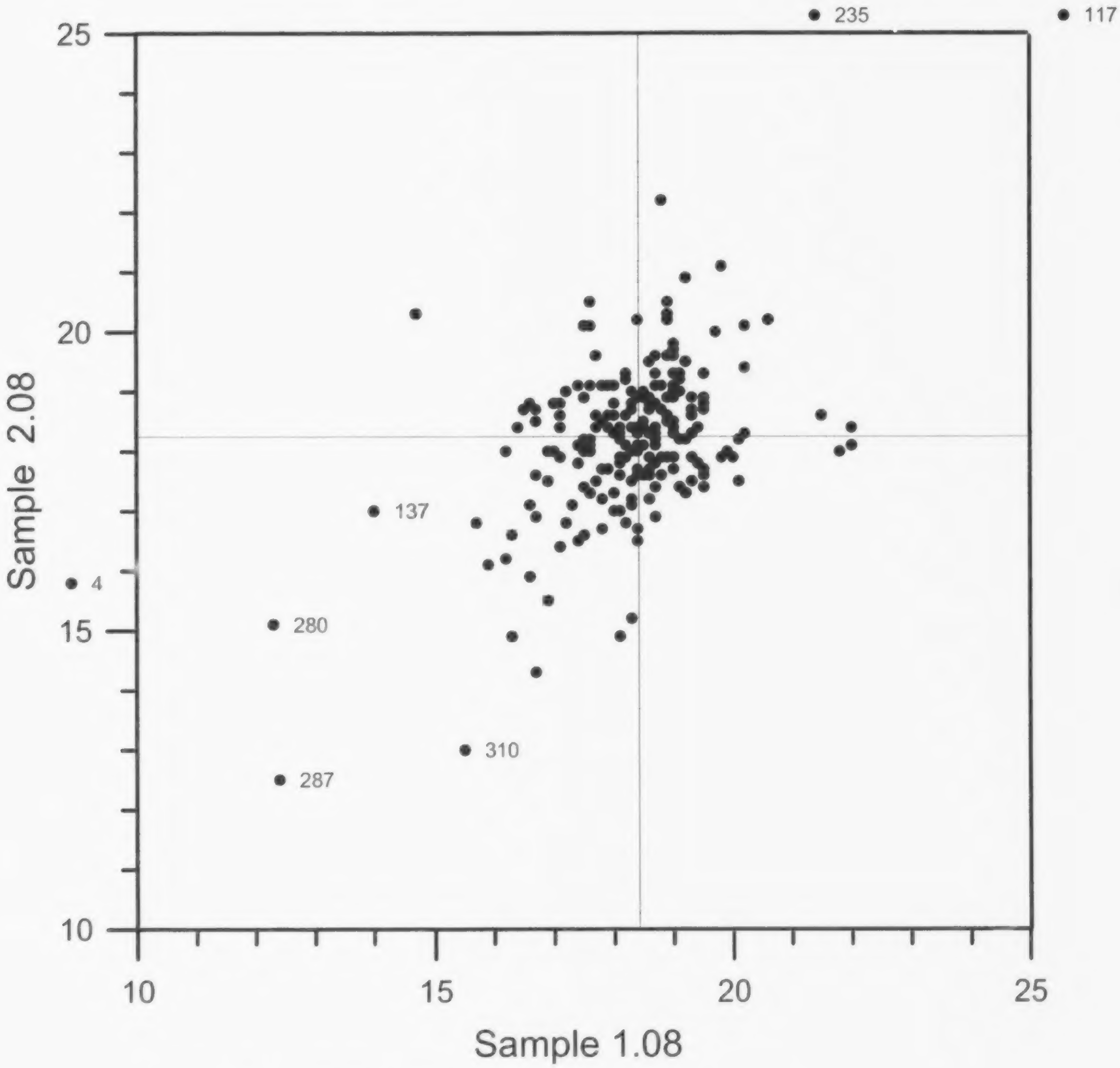
Test 22: Percent Passing the 600 um Sieve

	Mat 1	Mat 2
Mean	26.466	26.290
Median	26.100	26.050
Std Dev	1.657	1.636

n = 209

Lab Eliminated: 4; 117; 235; 287

2008 MTO AGGREGATE AND SOIL
PROFICIENCY SAMPLE TESTING PROGRAM



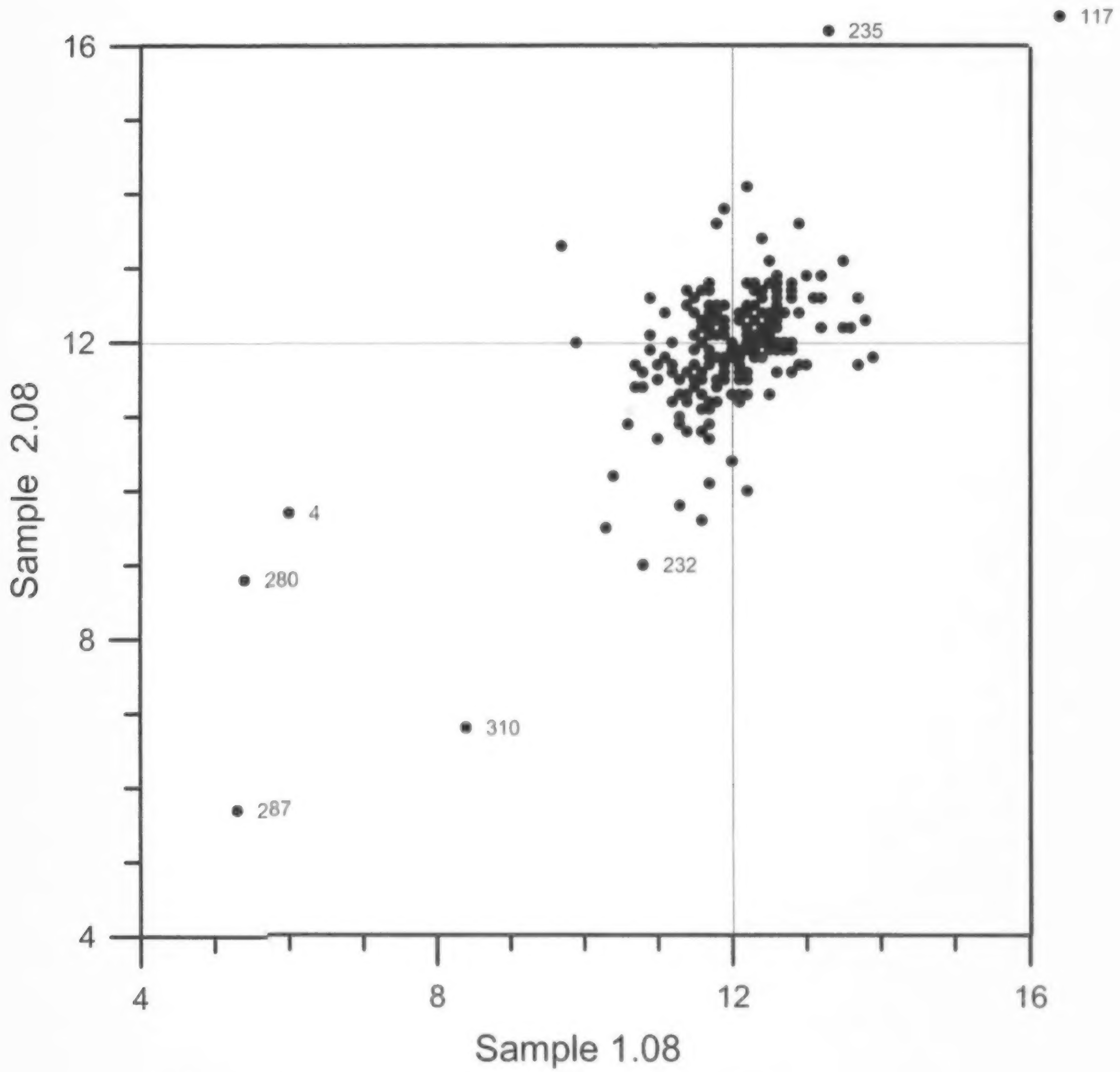
Test 23: Percent Passing the 300 um Sieve

	Mat 1	Mat 2
Mean	18.374	18.235
Median	18.350	18.250
Std Dev	1.107	1.123

n = 206

Lab Eliminated: 4; 117; 137; 235; 280; 287; 310

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



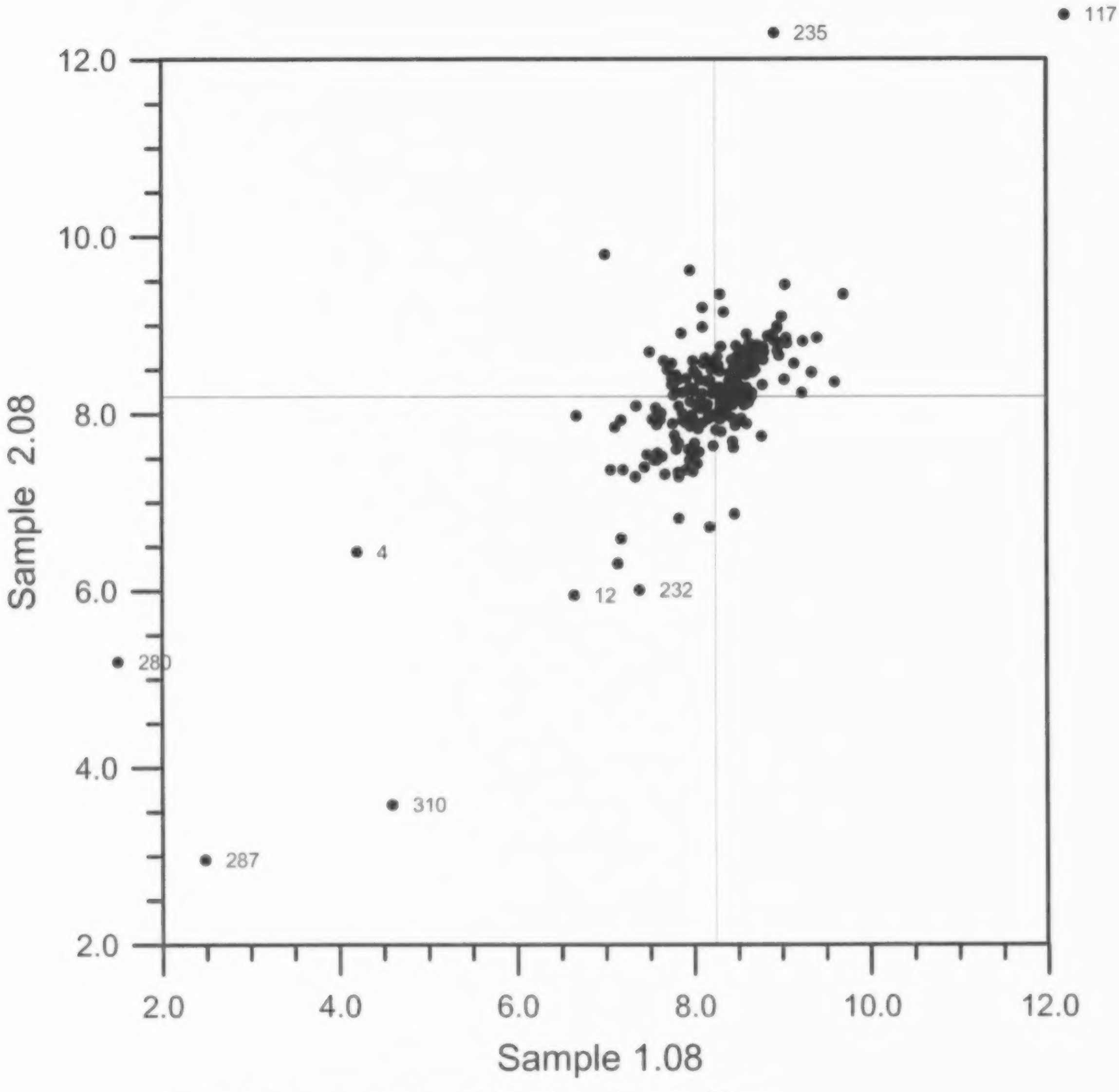
Test 24: Percent Passing the 150 um Sieve

	Mat 1	Mat 2
Mean	12.025	11.962
Median	11.800	11.800
Std Dev	0.691	0.713

n = 206

Lab Eliminated: 4; 117; 232; 235; 280; 287; 310

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



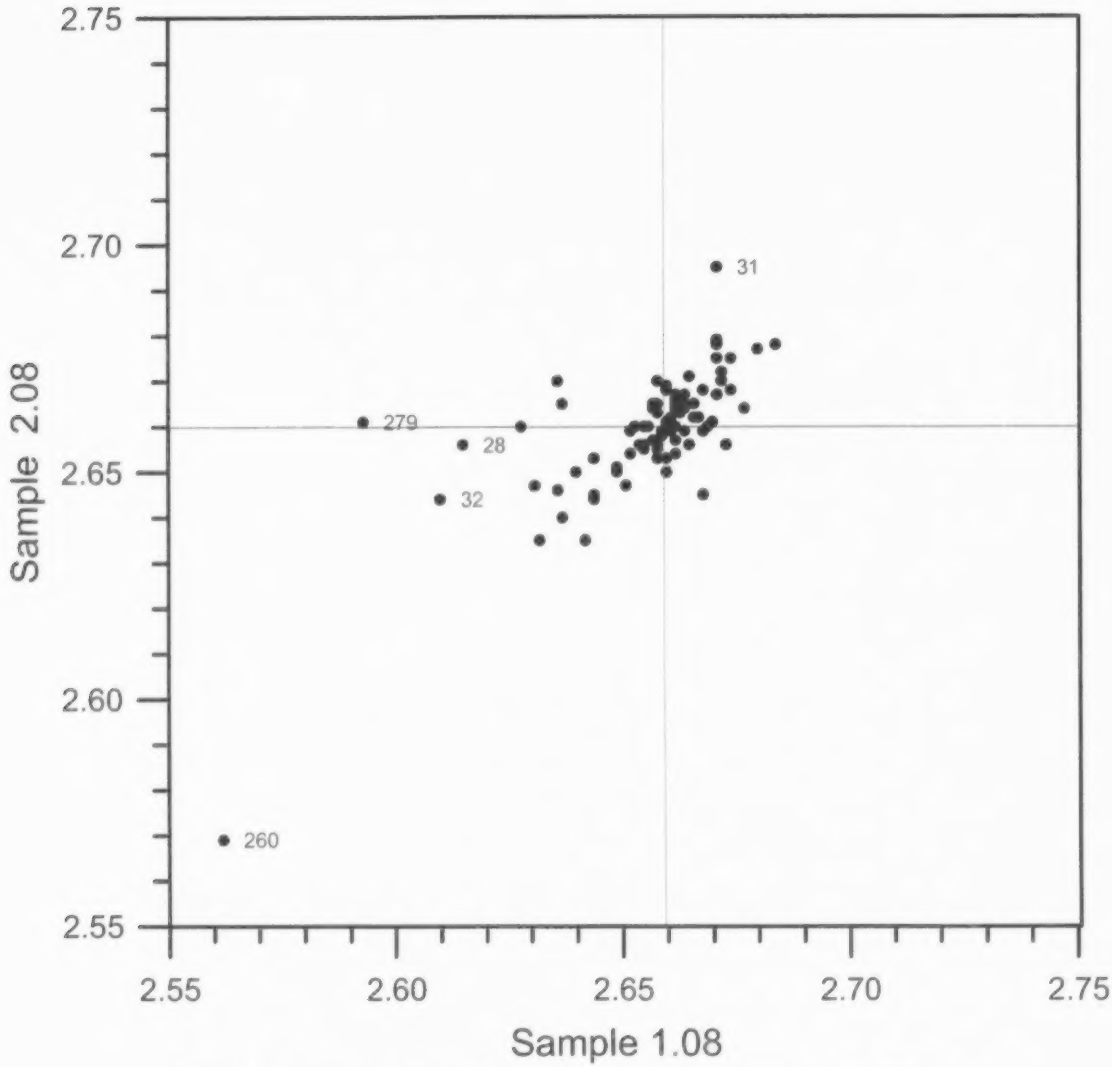
Test 25: Percent Passing the 75 um Sieve

	Mat 1	Mat 2
Mean	8.230	8.222
Median	8.185	8.055
Std Dev	0.511	0.536

n = 205

Labs Eliminated: 4; 12; 117; 232; 235; 280; 287; 310

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



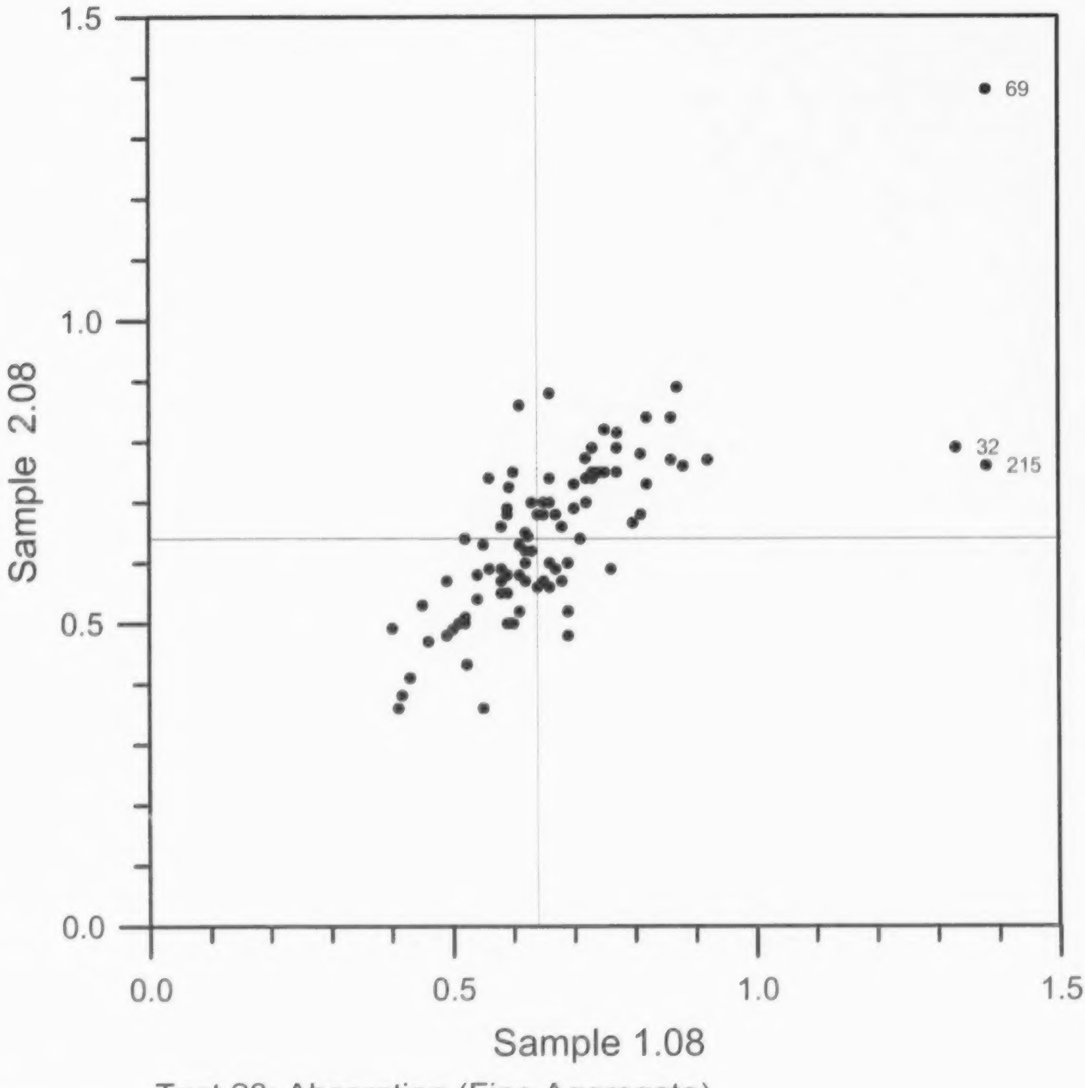
Test 27: Relative Density, (Fine Aggregate - Bulk)

	Mat 1	Mat 2
Mean	2.659	2.660
Median	2.656	2.657
Std Dev	0.011	0.009

n = 89

Labs Eliminated: 28; 31; 32; 260; 279

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



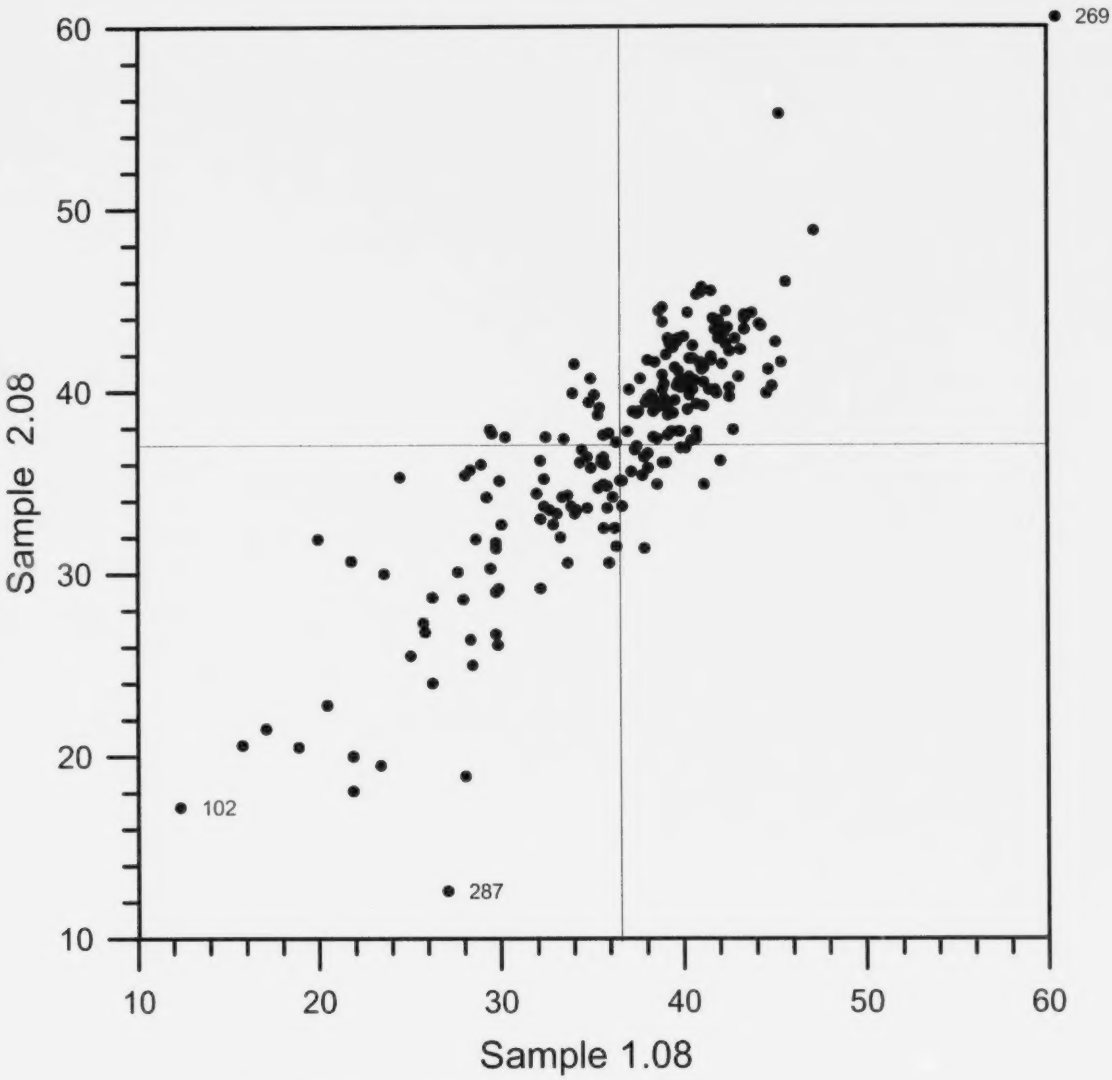
Test 28: Absorption (Fine Aggregate)

	Mat 1	Mat 2
Mean	0.644	0.642
Median	0.661	0.625
Std Dev	0.114	0.122

n = 91

Labs Eliminated: 32; 69; 215

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



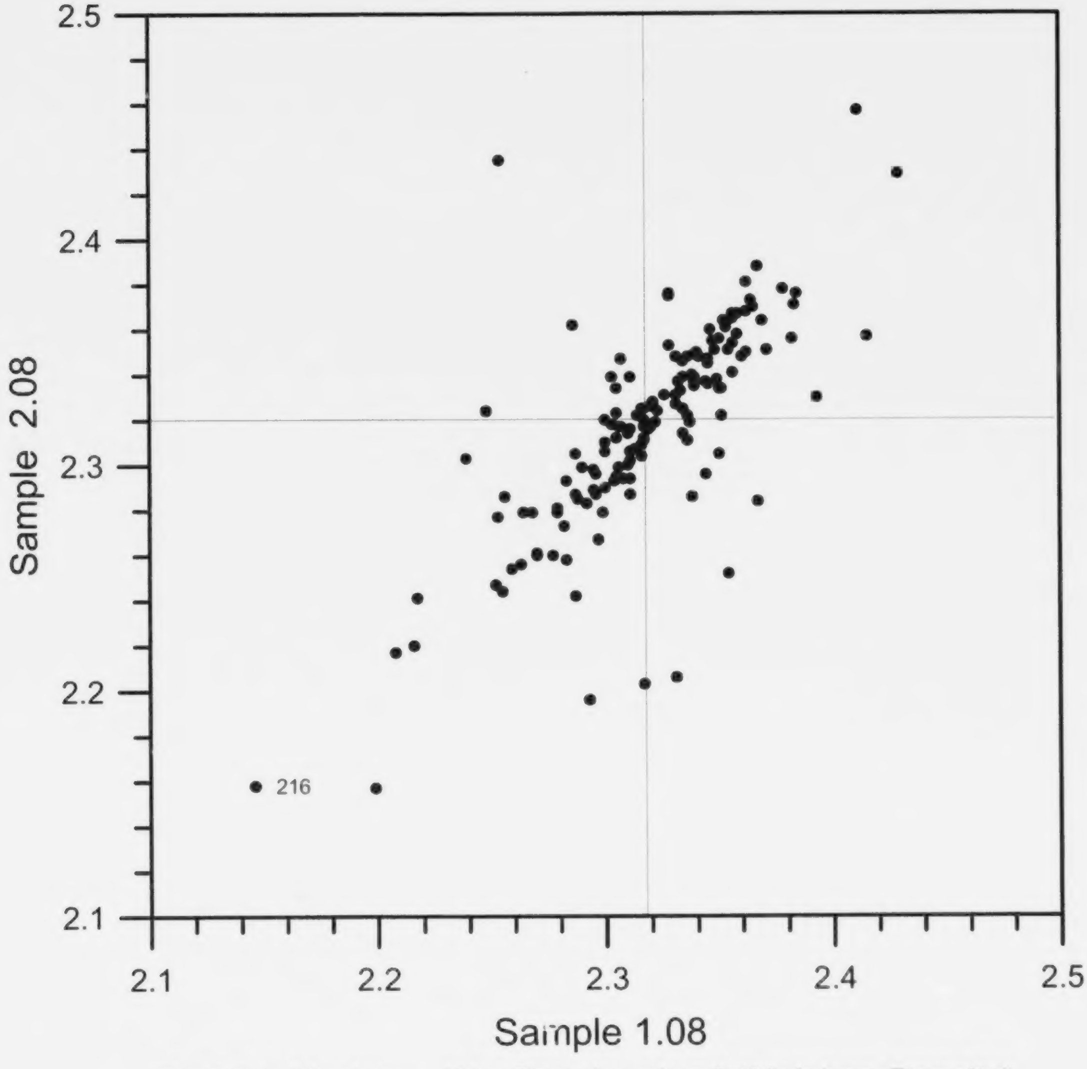
Test 30: Percent Asphalt Coated Particles

	Mat 1	Mat 2
Mean	36.530	37.139
Median	31.500	36.650
Std Dev	5.945	6.006

n = 210

Lab Eliminated: 102; 269; 287

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



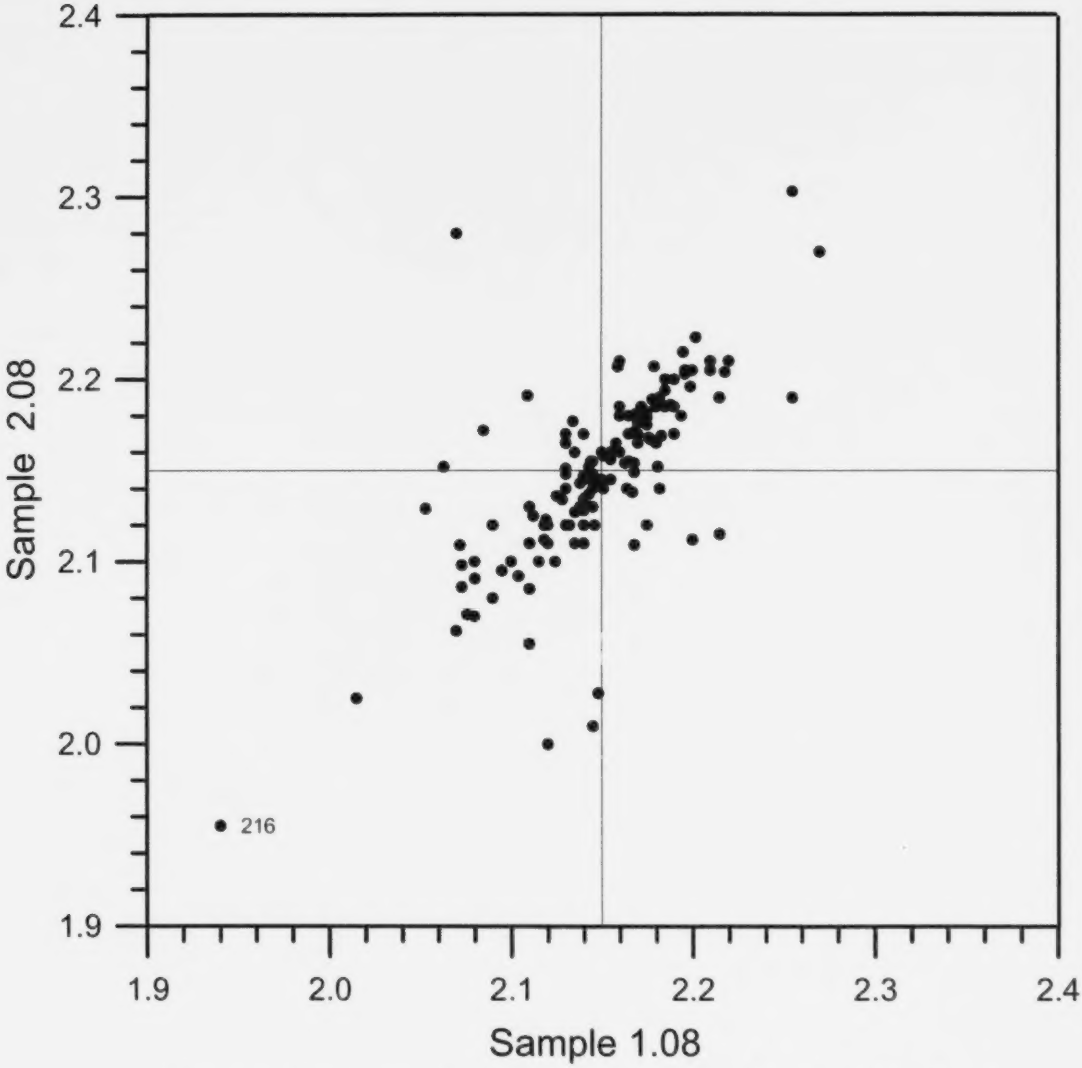
Test 31: Maximum Wet Density g/cm3 (Moisture-Density)

	Mat 1	Mat 2
Mean	2.320	2.317
Median	2.314	2.307
Std Dev	0.039	0.046

n = 151

Labs Eliminated: 216

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



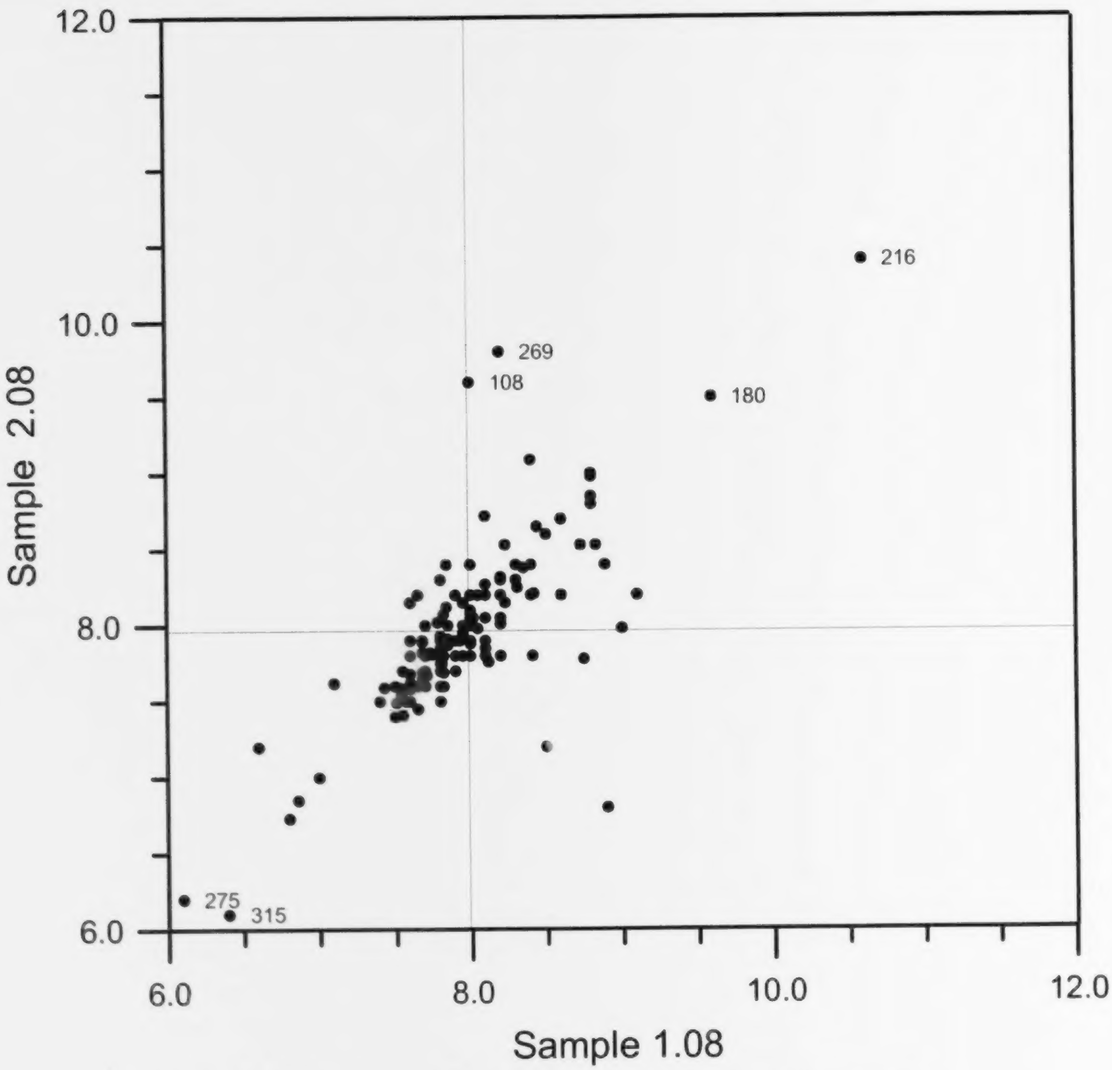
Test 32: Maximum Dry Density g/cm3 (Moisture-Density)

	Mat 1	Mat 2
Mean	2.151	2.151
Median	2.143	2.152
Std Dev	0.041	0.047

n = 151

Labs Eliminated: 216

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



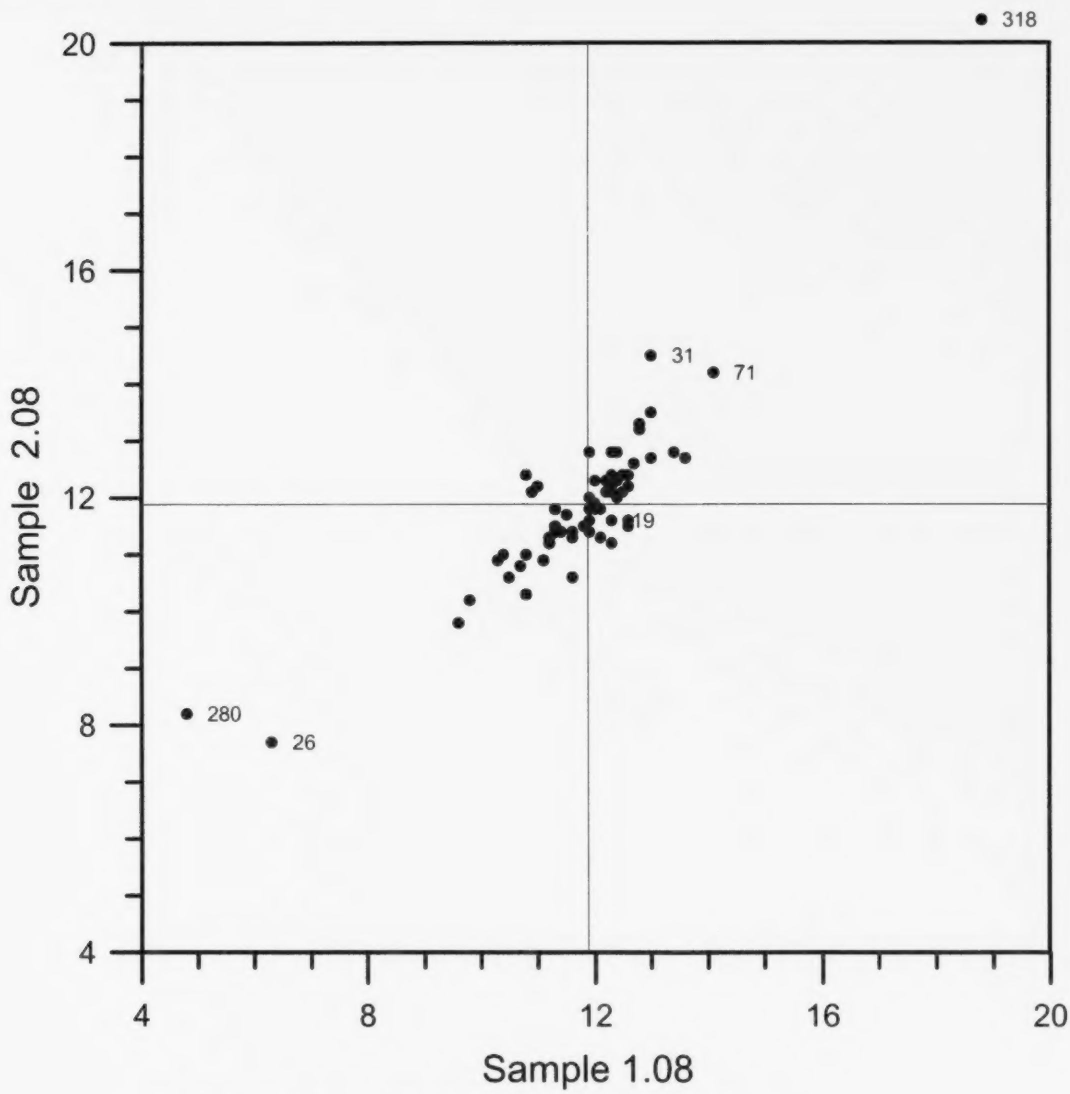
Test 33: Optimum Moisture, % (Moisture - Density)

	Mat 1	Mat 2
Mean	7.952	7.931
Median	7.850	7.910
Std Dev	0.448	0.396

n = 146

Labs Eliminated: 108; 180; 216; 269; 275; 315

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



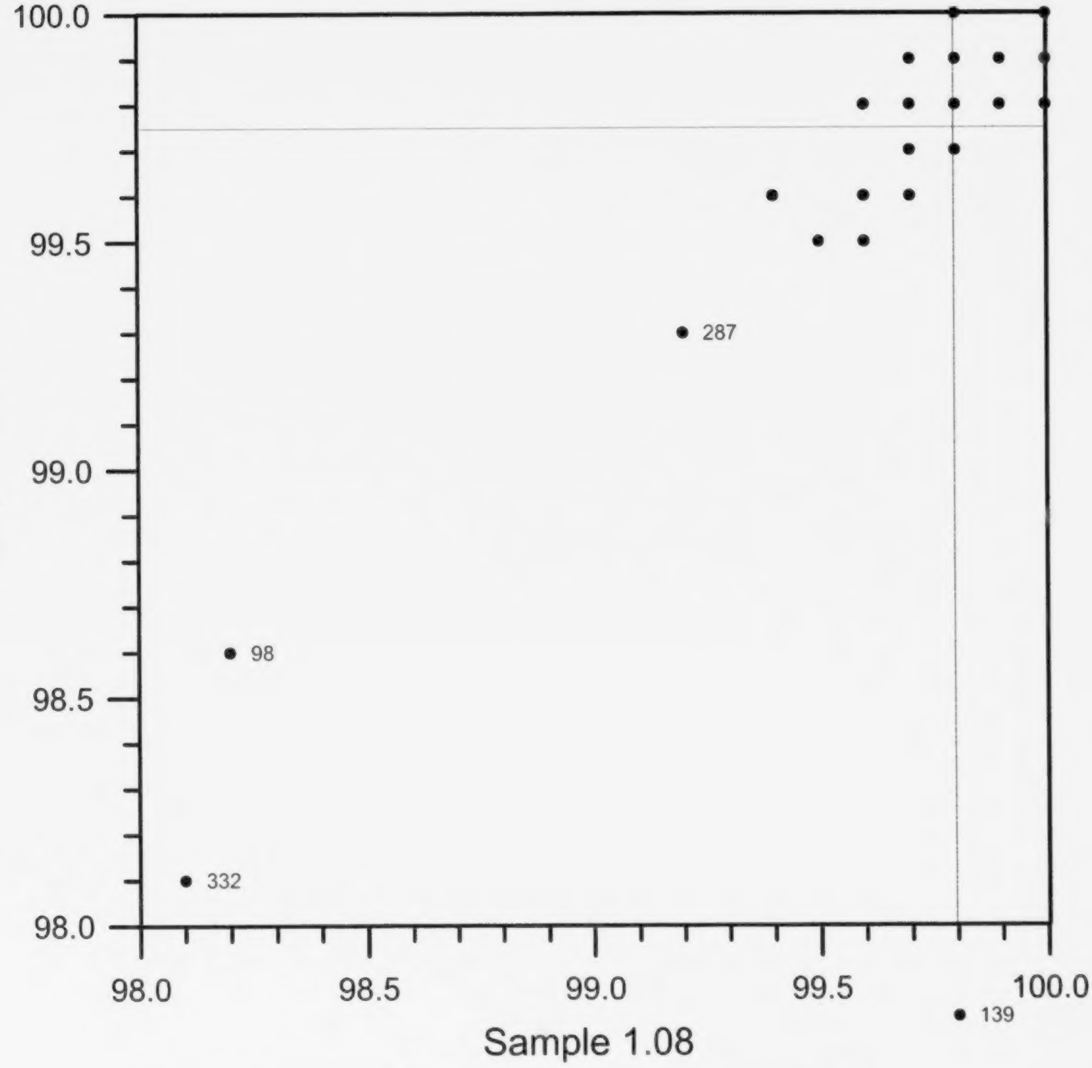
Test 34: Micro-Deval Abrasion Loss (FA), %

	Mat 1	Mat 2
Mean	11.868	11.798
Median	11.600	11.650
Std Dev	0.876	0.770

n = 63

Lab eliminated: 19; 26; 31; 71; 280; 318

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



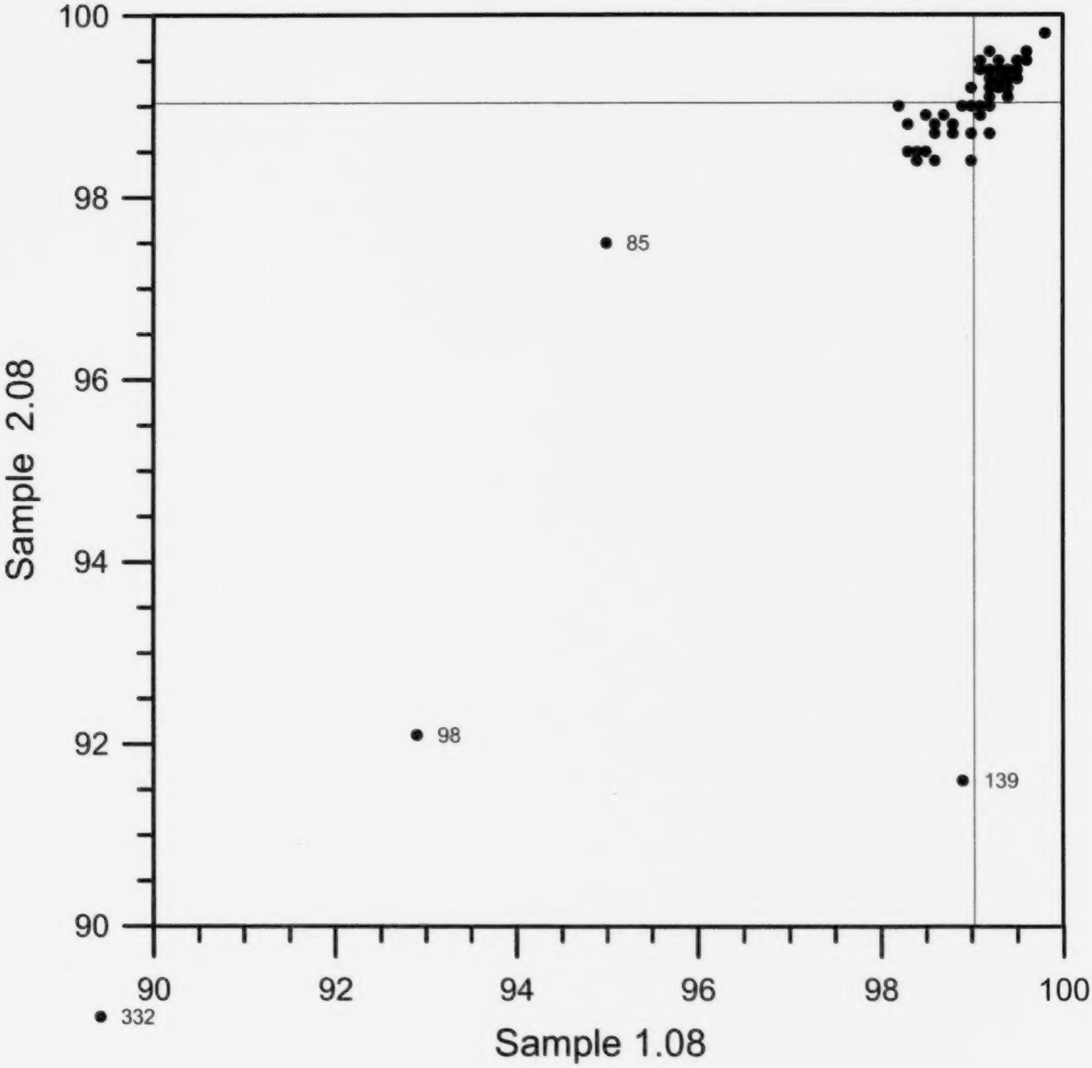
Test 41: Percent Passing the 425 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	99.803	99.806
Median	99.700	99.750
Std Dev	0.152	0.149

n = 66

Labs eliminated: 98; 139; 287; 332

2008 MTO AGGREGATE AND SOIL
PROFICIENCY SAMPLE TESTING PROGRAM



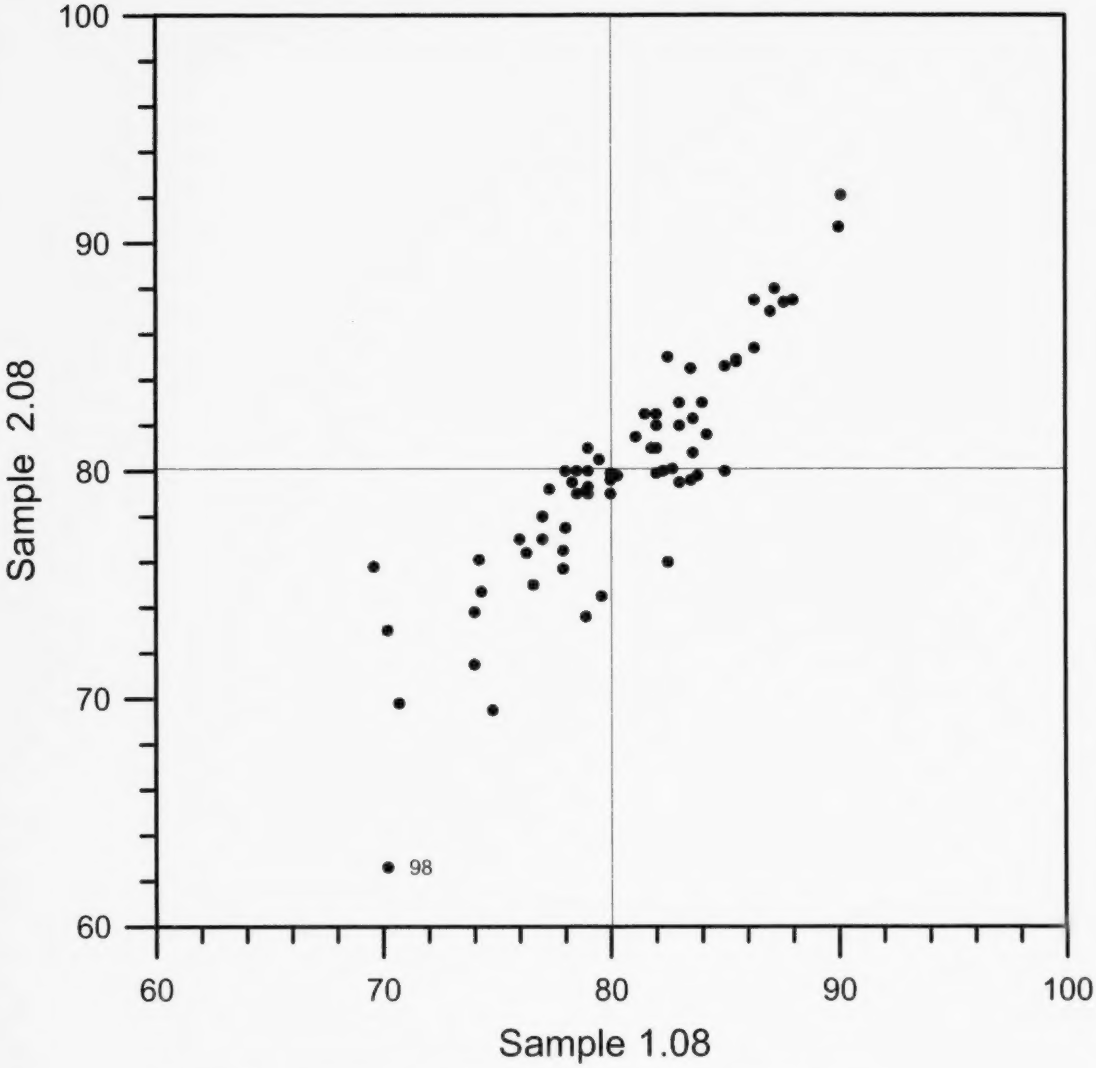
Test 42: Percent Passing the 75 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	99.079	99.098
Median	99.000	99.100
Std Dev	0.358	0.344

n = 66

Labs eliminated: 85; 98; 139; 332

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



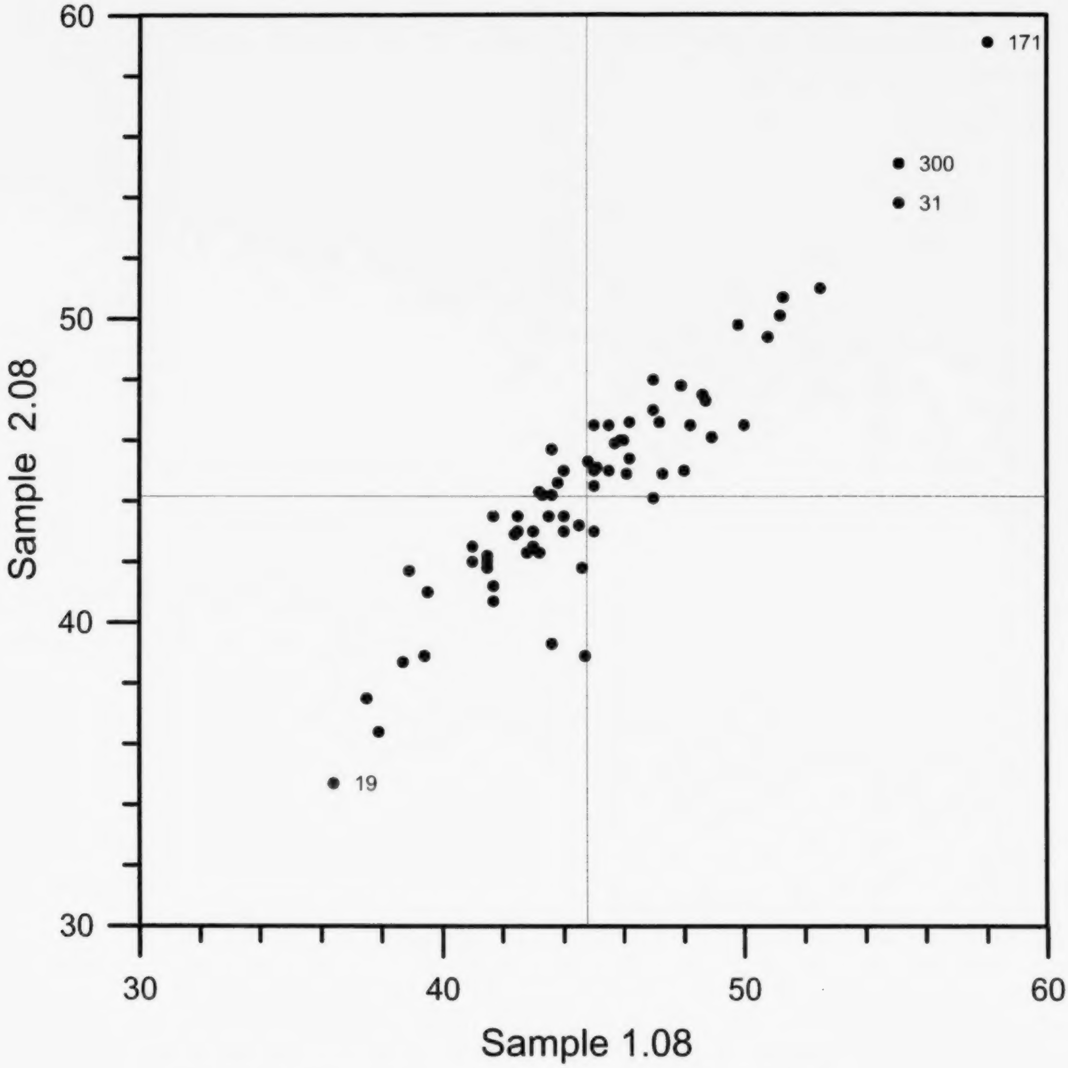
Test 43: Percent Passing the 20 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	80.394	80.070
Median	79.850	80.800
Std Dev	4.575	4.492

n = 69

Labs eliminated: 98

2008 MTO AGGREGATE AND SOIL
PROFICIENCY SAMPLE TESTING PROGRAM



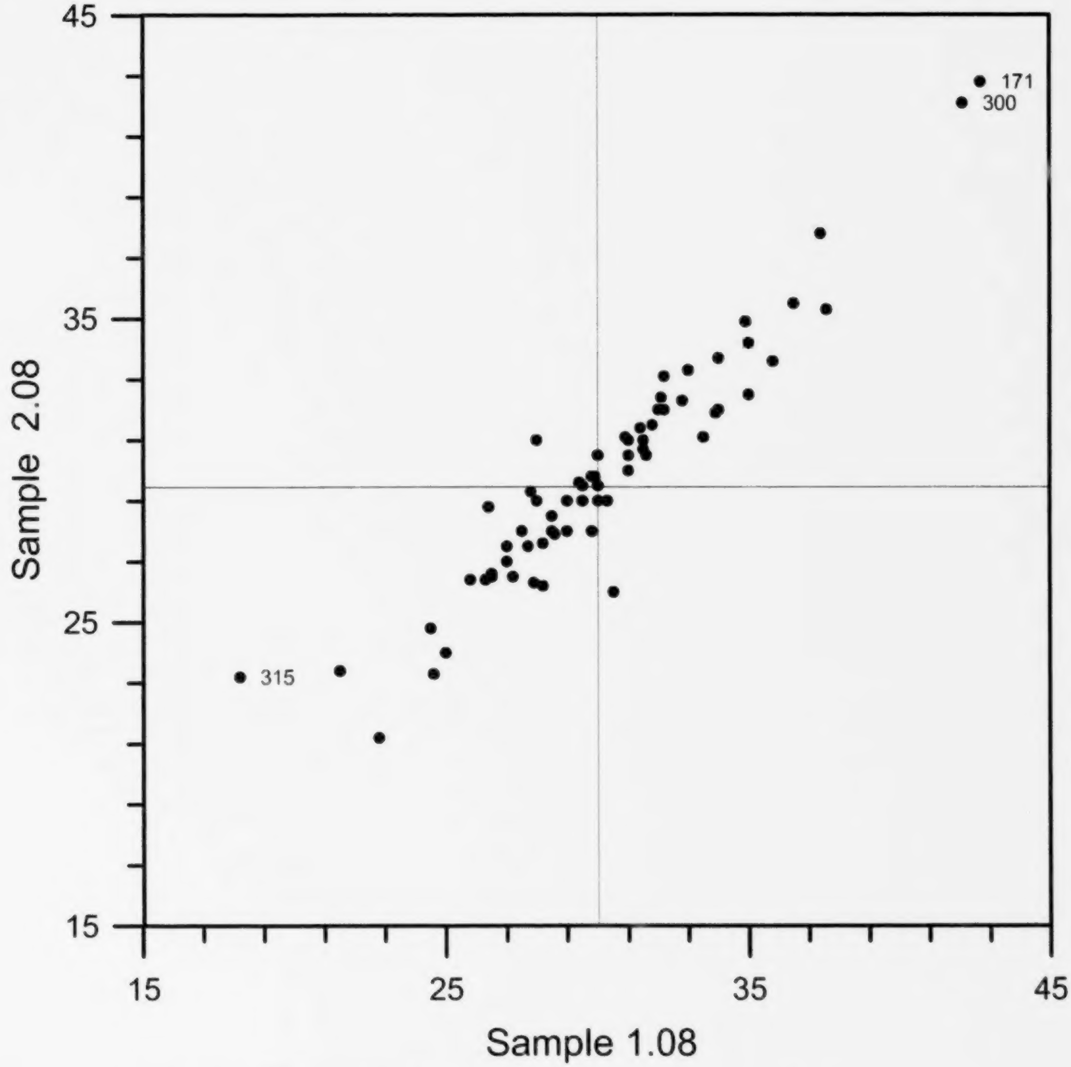
Test 44: Percent Passing the 5 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	44.830	44.241
Median	45.000	43.700
Std Dev	3.819	3.028

n = 66

Labs eliminated: 19; 31; 171; 300

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



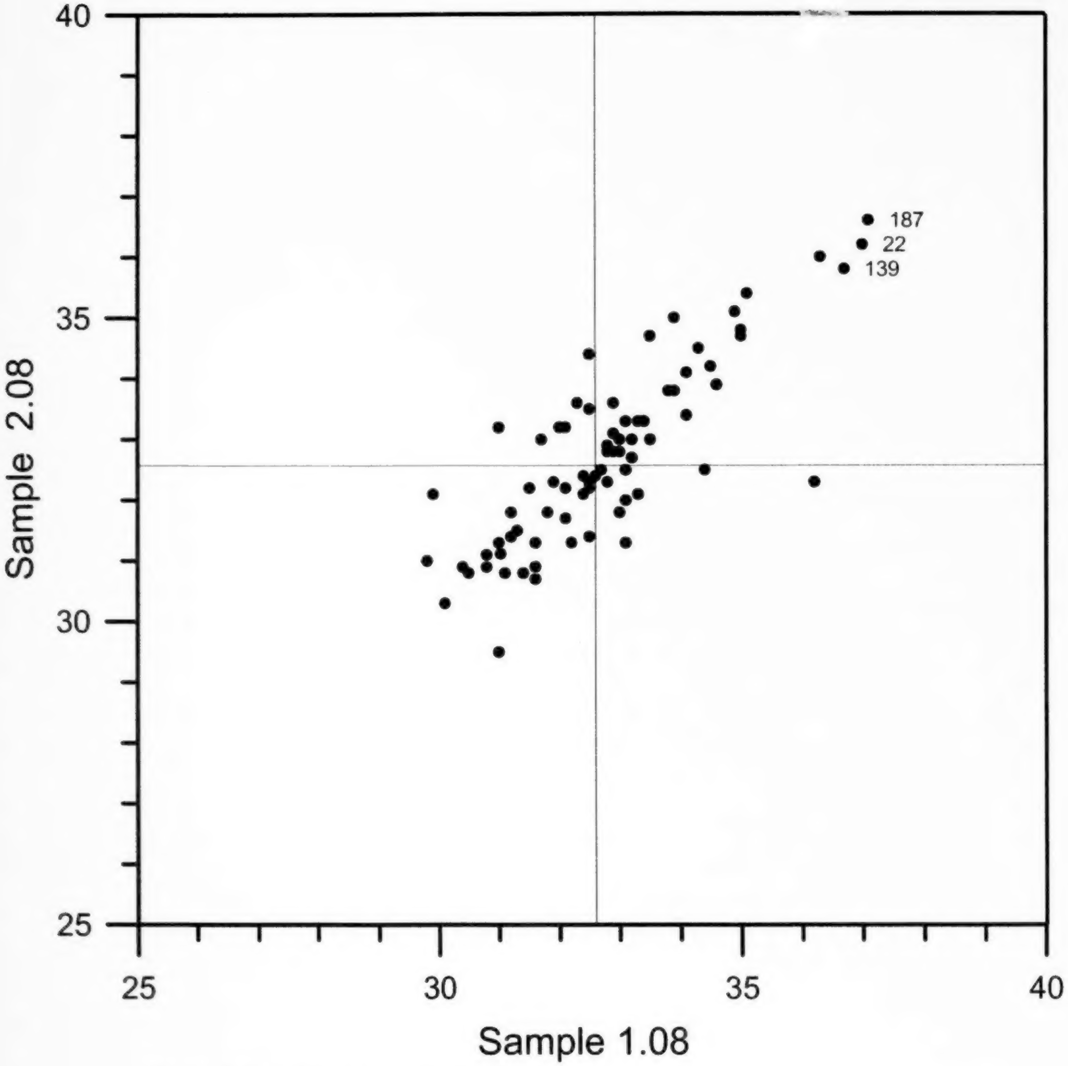
Test 45: Percent Passing the 2 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	29.915	29.432
Median	29.550	29.500
Std Dev	3.350	3.200

n = 67

LabsEliminated: 171; 300; 315

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



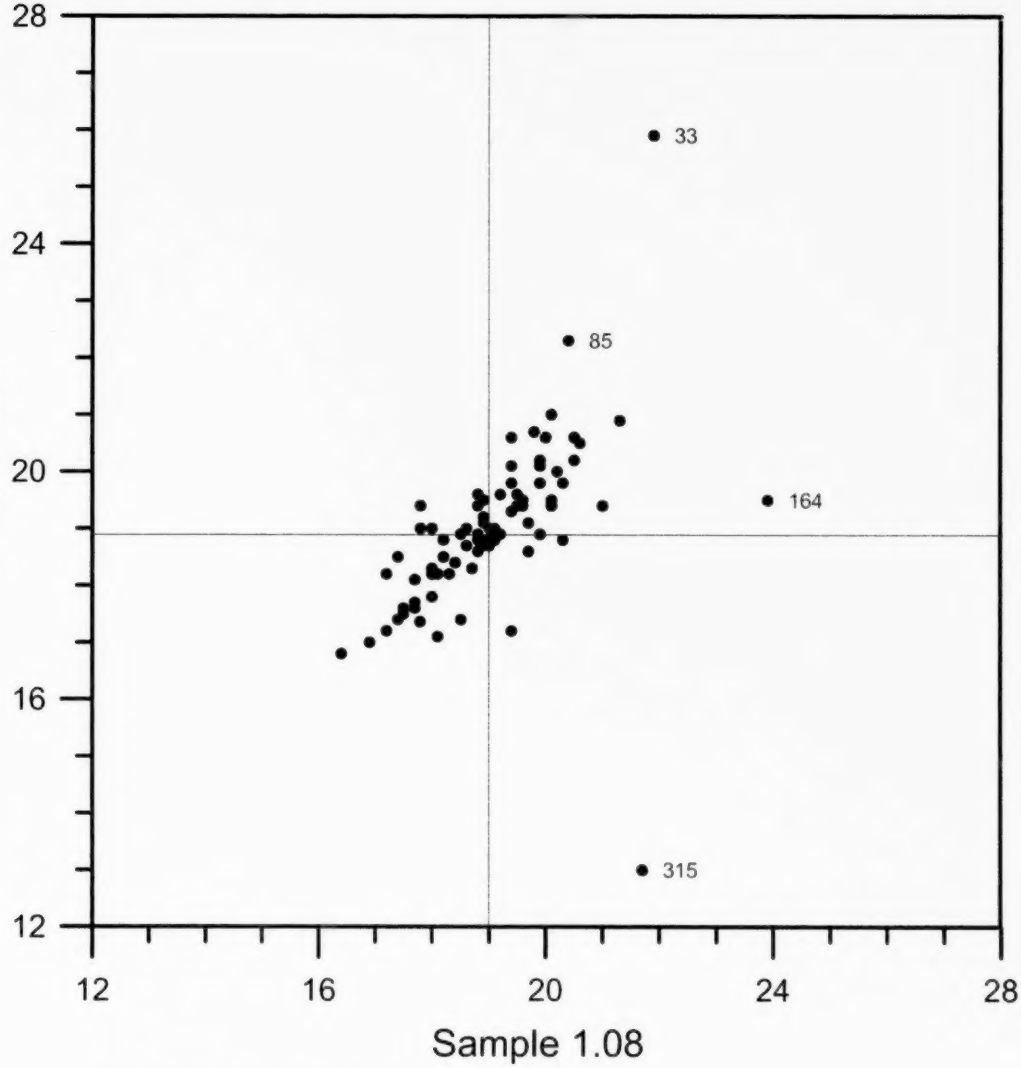
Test 46: Liquid Limit, %

	Mat 1	Mat 2
Mean	32.642	32.745
Median	33.050	32.750
Std Dev	1.375	1.458

n = 77

Lab eliminated: 22; 139; 187

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



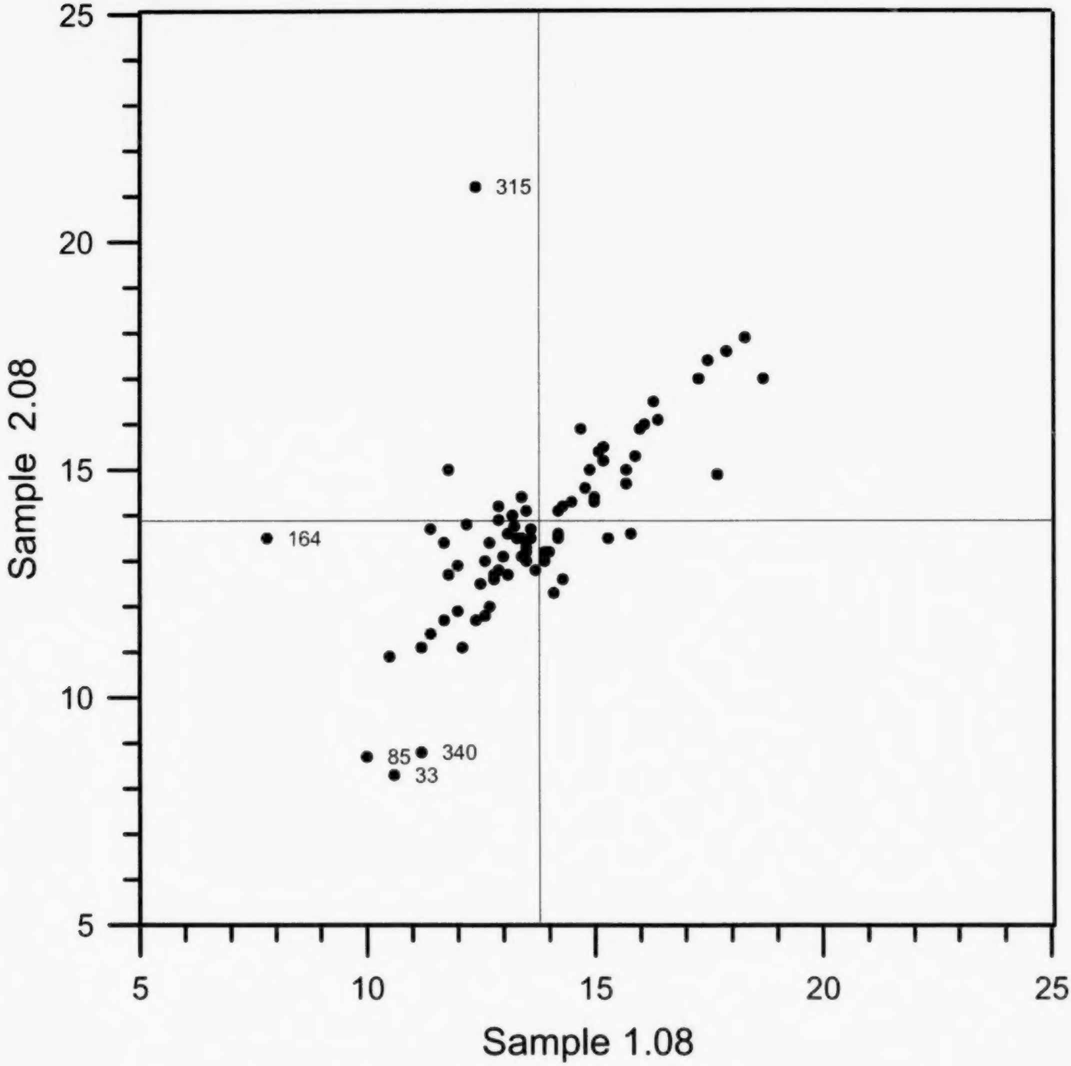
Test 47: Plastic Limit, %

	Mat 1	Mat 2
Mean	19.000	18.946
Median	18.850	18.900
Std Dev	1.110	0.985

n = 76

Labs eliminated: 33; 85; 164; 315

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



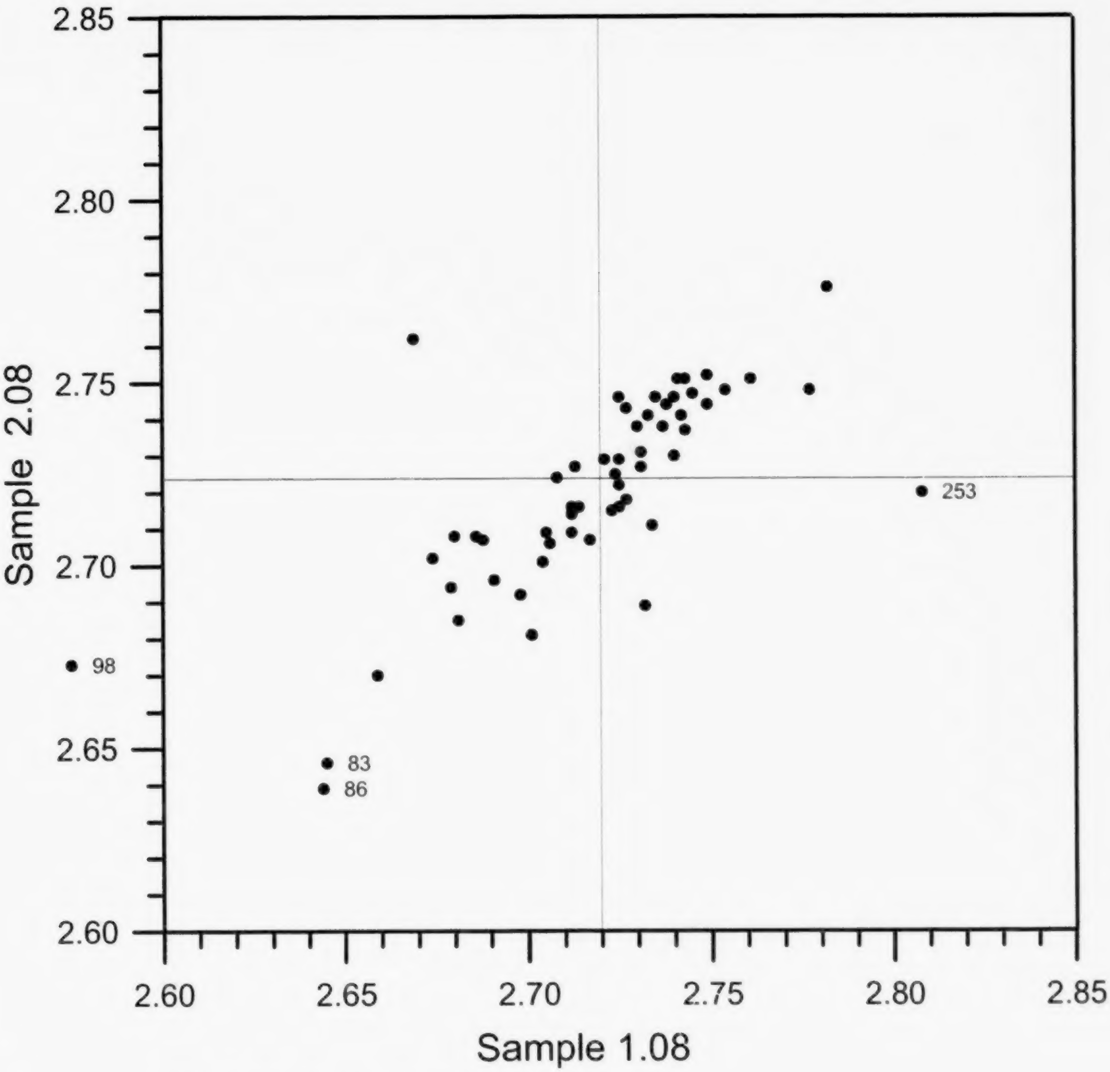
Test 48: Plasticity Index, %

	Mat 1	Mat 2
Mean	13.811	13.847
Median	14.600	14.400
Std Dev	1.844	1.536

n = 75

Lab eliminated: 33; 85; 164; 315; 340

2008 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



Test 49: Specific Gravity of Soil

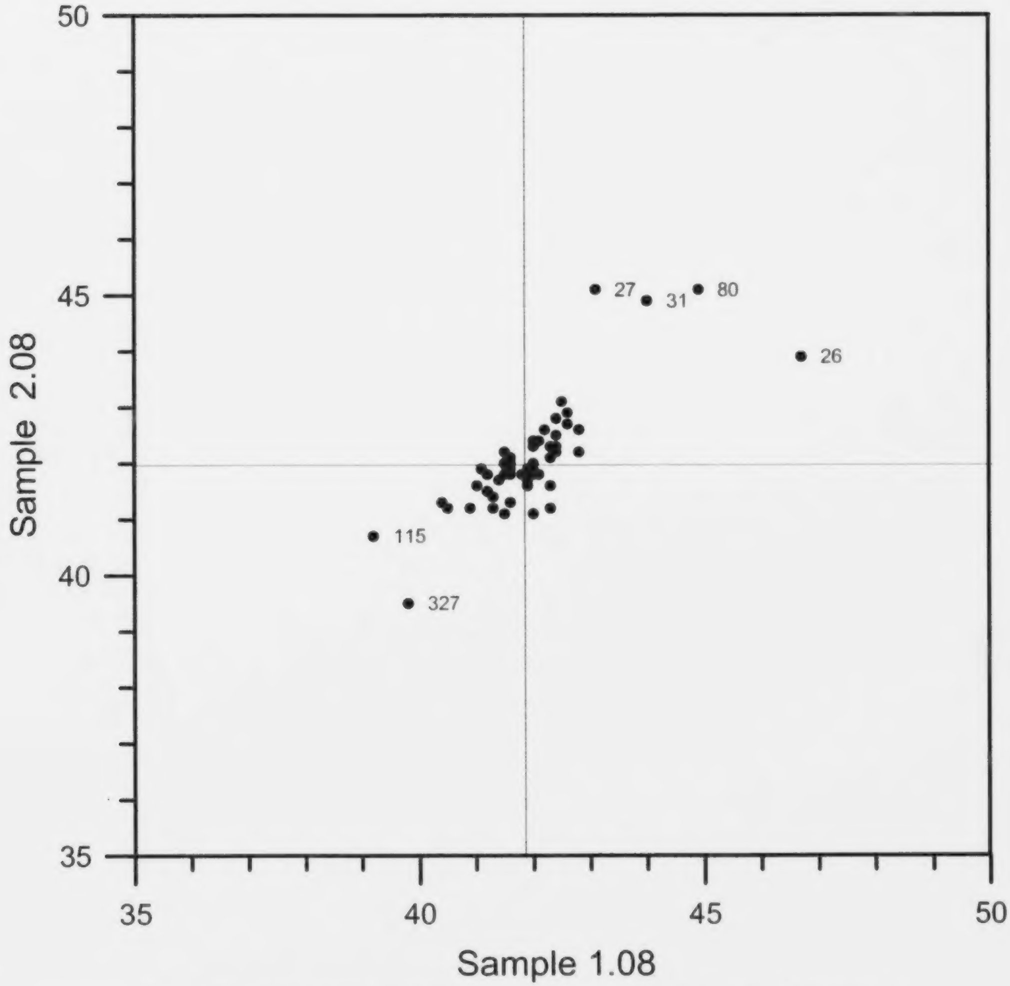
	Mat 1	Mat 2
Mean	2.719	2.724
Median	2.721	2.723
Std Dev	0.029	0.023

n = 54

Labs Eliminated: 83; 86; 98; 253

Appendix D2: Scatter Diagrams

2008 MTO SUPERPAVE
CONSENSUS PROPERTY TESTING PROGRAM



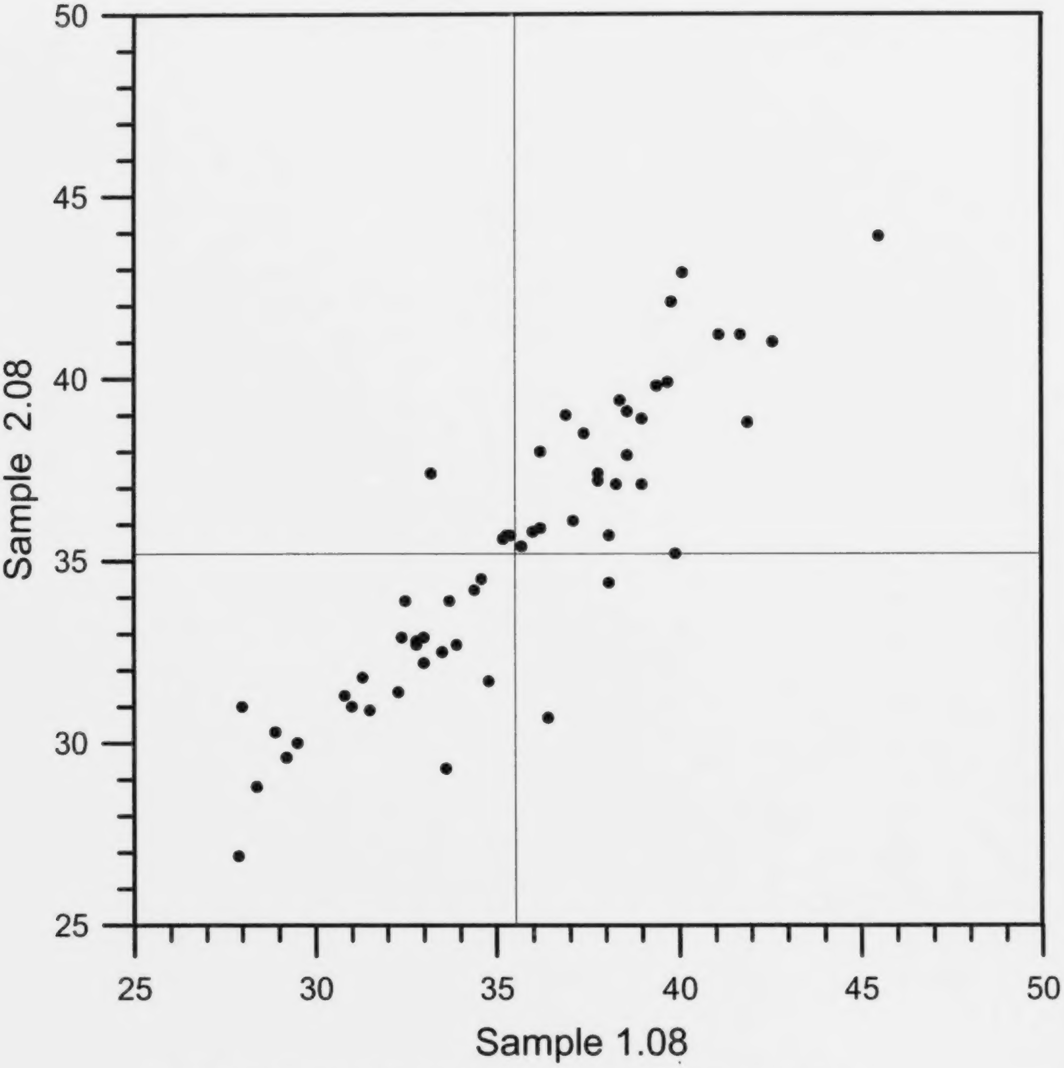
Test 95: Uncompacted Void Content of Fine Aggregate

	Mat 1	Mat 2
Mean	41.863	41.909
Median	41.600	42.100
Std Dev	0.575	0.538

n = 52

Labs eliminated: 26; 27; 31; 80; 115; 327

2008 MTO SUPERPAVE
CONSENSUS PROPERTY TESTING PROGRAM



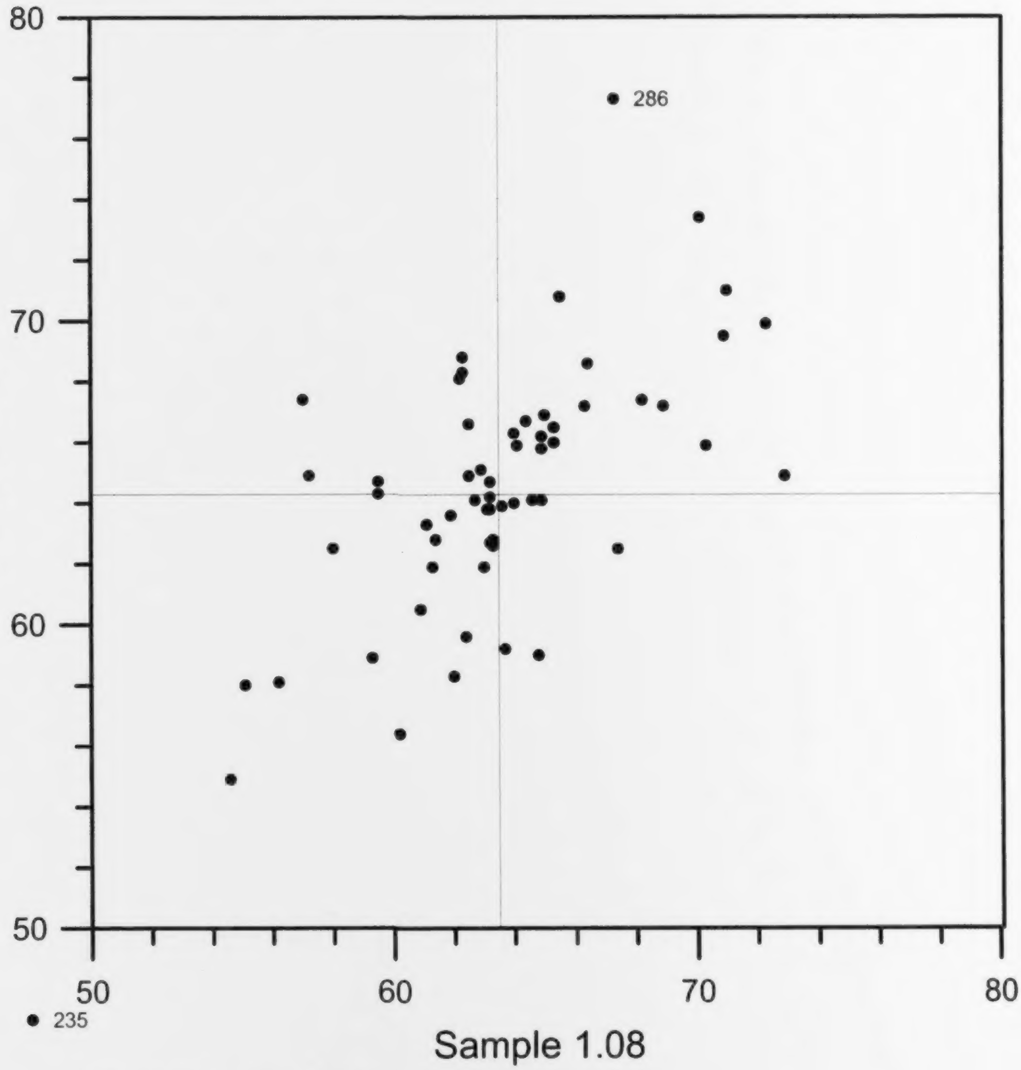
Test 96: Sand Equivalent Value of Fine Aggregate

	Mat 1	Mat 2
Mean	35.539	35.236
Median	36.700	35.400
Std Dev	4.009	3.954

n = 56

Labs eliminated: None

2008 MTO SUPERPAVE
CONSENSUS PROPERTY TESTING PROGRAM

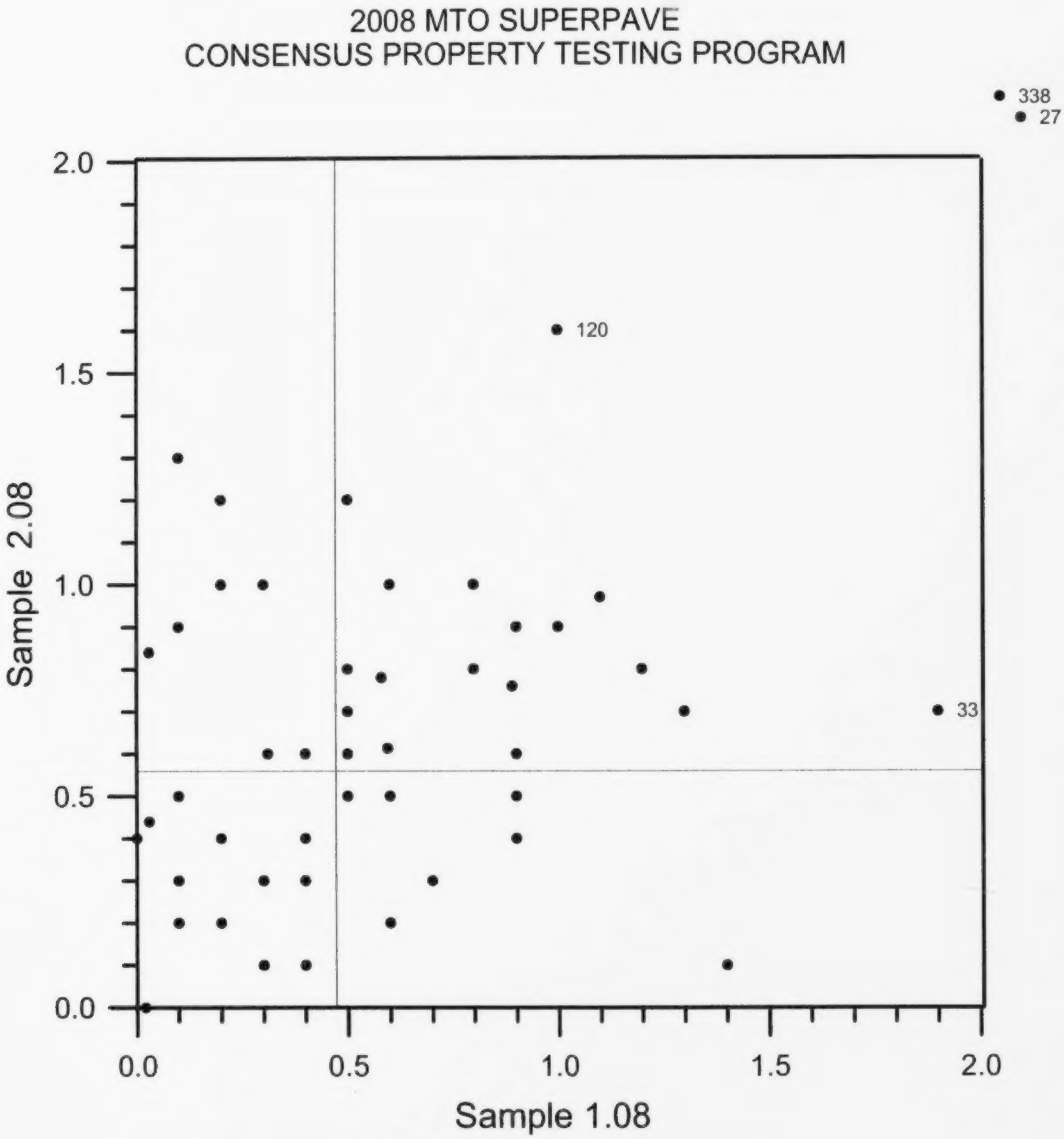


Test 97: Percent Fractured Particles

	Mat 1	Mat 2
Mean	63.585	64.403
Median	63.750	64.150
Std Dev	3.936	3.724

n = 58

Labs Eliminated: 235; 286



Test 99: Percent Flat and Elongated Particles

	Mat 1	Mat 2
Mean	0.482	0.560
Median	0.700	0.650
Std Dev	0.351	0.315

n = 56

Lab Eliminated: 27; 33; 120; 338

Appendix E1: Production Laboratory Ratings

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
4	6	3.5	0	3	10	32
10	10	28.9	10	9		97
12	10	14.2	10	10	2	66
13	10	28.6	9	10	6	91
15	10	29.2	10	9	10	97
16	10	21.0	1	6	10	69
17	9	25.4	10	7		86
18	10	28.1	10	10	10	97
19	10	28.1	10	10	10	97
20	9	27.0	9	10		92
22	10	29.7	10	9	10	98
23	7	30.0	5	10	8	86
25	10	25.1	7	10	10	89
26	0	27.0	9	10	9	79
27	10	29.5	6	10	7	89
28	8	18.0	9	9	10	77
29	10	24.8	8	10		88
30	10	29.5	2	10	10	88
31	10	28.9	9	10	6	91
32	8	29.2	10	9	9	93
33	10	28.9	10	10	10	98
34	10	25.1	9	10		90
35	10	29.7	10	10	10	100
37	10	29.5	9	8	10	95
38	10	23.5	4	9	10	81
39	10	28.4	10	10	9	96
43	9	28.1	10	10	10	96
44	10	30.0	10	10		100
45	10	27.3	5	6	10	83
46	9	27.8	9	8	10	91
47	10	30.0	10	10	10	100
54	9	29.2	10	10	9	96
56	10	24.5	3	10	10	82
58	10	30.0	9	10	7	94
59	8	29.2	10	10	10	96
60	9	25.1	0	2		60
61	10	27.0	10	10	9	94
62	6	22.1	10	6	10	77
64	10	22.1	10	7	10	84

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
68	10	27.3	9	10	2	83
69	10	27.5	10	9	10	95
71	10	26.5	10	9	10	94
72	8	27.8	8	10		90
73	5	28.6	3	8	0	64
79	10	29.5	10	10	10	99
80	10	30.0	10	10	10	100
81	10	27.5	10	10	2	85
83	10	25.9	10	10	10	94
85	10	25.4	10	10	8	91
86	10	28.6	10	9	9	95
90	9	29.2	9	6	9	89
94	10	27.5	9	3		83
98	10	25.9	0	8	0	63
100	10	21.5	8	10	10	85
101	10	29.5	10	10	10	99
102	10	28.4	10	0	10	83
103	9	29.2	8	10	9	93
104	10	22.9	10	10	9	88
105	10	29.7	10	10	7	95
107	10	29.5	10	10	10	99
108	7	28.9	10	10	10	94
110	10	30.0	8	10	10	97
112	10	26.7	8	10	10	92
113	6	28.4	9	10	10	91
115	10	27.3	9	9	0	79
116	10	27.5	10	10	10	96
117	8	12.5	10	10	0	58
120	7	29.7	10	10	8	92
124	10	23.5	10	9	10	89
126	7	24.8	9	10		85
127	10	19.6	10	10	10	85
128	6	29.7	10	9	10	92
129	10	30.0	9	10	8	96
134	10	29.7	9	8	6	90
136	10	28.9	5	9	10	90
137	9	18.3	10	10	10	82
138	9	29.7	10	10	10	98
139	10	26.5	9	10		92
141	9	28.1	10	9	10	94
144	4	29.7	9	10	7	85
146	10	27.3	7	10	10	92
147	10	12.3	10	10	4	66
153	9	27.8	5	10		86

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
157	10	27.5	10	9	10	**95**
158	10	29.2	10	8	10	**96**
161	10	24.5	10	6	10	**86**
163	9	28.1	8	10		**92**
164	8	24.5	9	10	10	**88**
167	10	29.7	7	8	10	**92**
169	1	28.4	10	10	10	**85**
171	10	27.0	9	10	8	**91**
172	10	28.9	10	10	10	**98**
175	9	28.9	10	10	6	**91**
176	10	22.6	7	10		**83**
177	10	30.0	10	10	10	**100**
178	10	28.9	8	7	10	**91**
179	9	29.2	10	4	9	**87**
180	9	27.8	10	10	10	**95**
181	6	29.5	10	10	9	**92**
182	7	29.5	6	10	10	**89**
184	10	28.9	9	10	10	**97**
187	10	28.4	10	10	9	**96**
188	8	27.8	10	10	10	**94**
191	8	30.0	8	10	10	**94**
193	10	29.2	10	9	10	**97**
194	10	28.4	10	6	10	**92**
198	10	29.5	8	1	0	**69**
199	10	30.0	10	9	9	**97**
200	10	28.1	10	10	9	**96**
201	9	29.7	10	10		**98**
202	9	29.2	9	8		**92**
204	5	19.1	0	2		**43**
205	10	28.4	10	1	10	**85**
207	10	27.3	10	10	10	**96**
208	10	29.5	10	9	2	**86**
210	6	27.5	9	10		**88**
214	10	29.7	8	8	8	**91**
215	10	21.8	9	9	10	**85**
216	8	29.7	10	10	9	**95**
217	9	28.4	9	9		**92**
218	9	30.0	6	10	10	**93**
219	10	23.7	10	9	10	**90**
221	10	28.4	10	10	9	**96**
223	8	28.1	9	9		**90**
224	8	27.0	10	10	10	**93**
228	10	27.5	10	10	10	**96**
232	10	18.0	10	10	10	**83**

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
234	7	27.8	10	9	9	**90**
235	9	16.1	10	10	7	**74**
236	8	30.0	6	8	9	**87**
237	9	28.9	9	10		**95**
245	10	29.5	9	9	10	**96**
246	10	29.7	10	10	10	**100**
247	6	27.5	10	9	10	**89**
248	10	27.3	4	10	8	**85**
249	10	30.0	10	10	10	**100**
250	10	28.4	7	10	9	**92**
251	10	28.1	10	10	10	**97**
252	10	27.0	9	7		**88**
253	0	23.2	10	10	3	**66**
254	10	27.0	10	10	10	**96**
255	9	27.5	10	9	10	**94**
256	10	28.6	10	10	10	**98**
257	7	28.9	7	3		**77**
258	10	25.4	10	10	10	**93**
260	10	25.4	9	10	9	**91**
262	8	26.7	0	10	10	**78**
263	10	29.7	10	9	9	**97**
264	10	24.8	9	10	10	**91**
267	10	27.5	10	10	10	**96**
268	8	24.5	10	10	10	**89**
269	2	29.7	0	0		**53**
271	10	28.9	10	10	10	**98**
272	8	29.2	10	10	10	**96**
273	10	30.0	10	10	10	**100**
274	10	28.9	10	10	9	**97**
275	9	28.9	9	7	10	**91**
276	10	28.6	10	9	10	**97**
277	10	29.5	10	9	9	**96**
278	10	23.5	8	10	10	**88**
279	10	28.4	10	10	8	**95**
280	10	17.5	10	10	8	**79**
282	9	26.7	10	10	10	**94**
284	5	25.1	9	6	0	**64**
285	10	27.5	10	9	10	**95**
286	10	29.5	9	10		**97**
287	6	7.9	9	3		**43**
288	5	23.2	0	9	9	**66**
290	10	23.7	10	10	10	**91**
291	10	16.9	8	5		**67**
293	10	28.9	10	10		**98**

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
294	10	29.2	10	10	10	**99**
295	10	27.5	10	10	10	**96**
296	6	29.7	10	10	10	**94**
297	10	23.7	9	9	0	**74**
298	10	28.1	10	10	10	**97**
299	10	26.2	10	10	10	**95**
300	10	29.5	8	10	10	**96**
301	10	20.7	10	10	7	**82**
302	6	28.1	10	4	10	**83**
303	4	17.7	10	8	10	**71**
305	10	27.3	10	9		**94**
308	10	28.9	10	10		**98**
309	10	28.1	0	10	7	**79**
310	9	18.3	0	10	9	**66**
311	9	28.9	10	10	10	**97**
312	5	29.7	10	10		**91**
313	10	29.7	10	7		**95**
314	9	27.0	7	10	9	**89**
315	10	25.9	10	9	10	**93**
316	10	27.8	10	10	10	**97**
317	10	26.2	10	9	10	**93**
318	0	24.5	1	9	8	**61**
320	10	29.2	10	9		**97**
321	10	27.8	10	10	9	**95**
322	10	29.7	10	10		**100**
323	10	28.9	6	10	9	**91**
324	9	28.1	10	6	10	**90**
325	10	29.7	8	10	10	**97**
326	10	21.0	10	10	10	**87**
327	9	28.9	10	10	10	**97**
328	10	28.1	10	10	10	**97**
329	10	21.8	9	10	10	**87**
330	10	22.9	9	9	10	**87**
331	10	22.9	9	*9*		**85**
332	10	20.2	10	*10*	10	**86**
333	6	25.6	10	*9*	8	**84**
334	9	26.7	10	*10*	10	**94**
335	10	27.3	9	*10*		**94**
337	4	21.5	8	*8*	9	**72**
338	9	24.5	8	*10*		**86**
339	10	26.5	7	*10*	10	**91**
340	10	29.2	10	*9*	9	**96**

Appendix E2: Full Service Aggregate Laboratory Ratings

FULL SERVICE AGGREGATE LABORATORY RATINGS 2008

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-603 LAA	LS-604 BRD/ABS (CA)	LS-606 $MgSO_4$ (CA)	LS-607 % Crush	LS-621 % Asphalt	LS-608 % Flat & Elongated	LS-618 MDA (CA)	LS-614 F/T	LS-605 BRD/ABS (FA)	LS-623 One-Point Proctor	LS-619 MDA (FA)	Rating
13	10	28.6		8.5	10	9	10	6	9	10	10.0	10.0	9	**93**
15	10	29.2		10.0	10	10	9	10	10	10	7.0	8.0	10	**95**
18	10	28.1		8.5	9	10	10	10	10	8	10.0	10.0	10	**95**
19	10	28.1		10.0		10	10	10	9	10	10.0	9.3	0	**90**
22	10	29.7		9.0		10	9	10	10	5	8.5	9.7	10	**93**
23	7	30.0		10.0	10	5	10	8	10	8	10.0	10.0	10	**91**
27	10	29.5	8	8.0	6	6	10	7	8	10	10.0	10.0	7	**86**
28	8	18.0		8.5		9	9	10	3	2	7.5	9.0	8	**71**
31	10	28.9	3	10.0	10	9	10	6	9	8	6.5	10.0	4	**83**
35	10	29.7	10	10.0	8	10	10	10	10	10	8.0	9.3	7	**95**
37	10	29.5	9	10.0	10	9	8	10	10	10	10.0	9.7	10	**97**
38	10	23.5	6	8.5	9	4	9	10	10	10	9.5	10.0	10	**86**
39	10	28.4		10.0		10	10	9	7	10	8.5	10.0	7	**92**
47	10	30.0	10	7.5		10	10	10	4	10	10.0	10.0	10	**94**
56	10	24.5	10	9.0	9	3	10	10	9	10	7.5	10.0	10	**88**
59	8	29.2		10.0	9	10	10	10	10	10	7.5	10.0	10	**95**
61	10	27.0		8.5	7	10	10	9	8	9	7.5	10.0	10	**90**
69	10	27.5		9.0		10	9	10	9	9	1.5	10.0	9	**88**
79	10	29.5		8.5		10	10	10	10	10	9.5	10.0	10	**98**
80	10	30.0	9	8.5	8	10	10	10	9	10	10.0	9.3	8	**95**
83	10	25.9		8.5	10	10	10	10	9	9	10.0	10.0	10	**95**
86	10	28.6		10.0		10	9	9	10	10	7.5	7.3	9	**93**
98	10	25.9		8.5	10	0	8	0	8	6	9.5	4.7	8	**70**
101	10	29.5	10	9.0	10	10	10	10	10	10	10.0	9.0	8	**97**
105	10	29.7	10	10.0	10	10	10	7	9		10.0	10.0	10	**97**

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-603 LAA	LS-604 BRD/ABS (CA)	LS-606 $MgSO_4$ (CA)	LS-607 % Crush	LS-621 % Asphalt	LS-608 % Flat & Elongated	LS-618 MDA (CA)	LS-614 F/T	LS-605 BRD/ABS (FA)	LS-623 One-Point Proctor	LS-619 MDA (FA)	Rating
107	10	29.5		8.0	8	10	10	10	4	9	10.0		10	**91**
108	7	28.9		8.0	6	10	10	10	9		10.0	5.7	6	**85**
110	10	30.0		10.0	9	8	10	10	10	8	10.0	10.0	7	**94**
112	10	26.7		9.0	4	8	10	10	10	3	10.0	7.3	10	**84**
124	10	23.5		10.0		10	9	10	7	10	9.0	10.0	10	**91**
157	10	27.5		9.5	10	10	9	10	8	10	10.0		10	**95**
164	8	24.5		9.5	10	9	10	10	10	10	10.0		10	**93**
172	10	28.9		7.5	10	10	10	10	0	10	7.0	9.7	10	**88**
177	10	30.0		10.0		10	10	10	10	10	10.0	10.0	9	**99**
188	8	27.8	10	9.5	10	10	10	10	10	10	10.0	10.0	10	**97**
199	10	30.0		10.0		10	9	9	9	10	8.5	10.0	10	**97**
205	10	28.4		10.0		10	1	10	10	10	8.5	10.0	10	**91**
216	8	29.7		8.0	10	10	10	9	10	9	10.0		6	**92**
245	10	29.5		9.5		9	9	10	7	8	10.0	9.3	2	**87**
260	10	25.4		9.0	7	9	10	9	6	10	3.0	7.7	10	**83**
263	10	29.7		10.0	10	10	9	9	8	10	6.0	10.0	10	**94**
285	10	27.5		10.0	10	10	9	10	6	10	9.5	10.0	10	**94**
295	10	27.5		10.0	10	10	10	10	10	10	10.0	10.0	10	**98**
296	6	29.7		10.0	10	10	10	10	10	10	10.0	9.3	10	**96**
298	10	28.1		9.5	10	10	10	10	10	10	10.0		10	**98**
301	10	20.7		8.0	10	10	10	7	10	9	9.0	10.0	4	**84**
316	10	27.8		10.0	10	10	10	10	10	10	8.5	10.0	10	**97**
326	10	21.0		9.5		10	10	10	6	7	10.0	10.0	9	**87**
340	10	29.2		7.0		10	9	9	9	8	8.0		10	**91**

Appendix E3: Soil Laboratory Ratings

Lab No.	LS-702 Hydrometer Analysis	LS-703 & 4 Atterberg Limits	LS-705 Specific Gravity	Rating
12	8.8	8.7	10	**92**
15	9.6	10.0	8	**92**
18	10.0	8.3	10	**94**
19	4.8	9.7	10	**82**
20	9.2	8.7	8	**86**
22	9.6	5.0	10	**82**
23	7.0	10.0	10	**90**
27	8.4	9.3	9	**89**
28	10.0	7.7	7	**82**
29	8.4	8.7	10	**90**
30	9.8	10.0	10	**99**
31	6.8	7.7	10	**82**
32	9.6	10.0	9	**95**
35	8.6	8.7	10	**91**
37	10.0	10.0	10	**100**
38	9.0	9.7	8	**89**
44	7.8	9.3	10	**90**
46	8.2	8.3	8	**82**
47	9.2	10.0	10	**97**
54	8.2	6.7	10	**83**
56	7.6	9.3	8	**83**
58	9.2	9.3	8	**88**
59	10.0	8.7	10	**96**
64	9.0	10.0	9	**93**
68	9.6	10.0	10	**99**
69	9.4	8.3	9	**89**
71	8.4	8.3	7	**79**
72	9.6	10.0	10	**99**
79	8.6	10.0	10	**95**
80	9.8	9.0	9	**93**
83	10.0	9.7	1	**69**
86	9.6	9.3	1	**66**
94	10.0	8.7	10	**96**
98	2.4	9.7	2	**47**
101	9.4	10.0	4	**78**
102	10.0	9.7	10	**99**
105	6.2	9.3	9	**82**
112	10.0	9.0	10	**97**

Lab No.	LS-702 Hydrometer Analysis	LS-703 & 4 Atterberg Limits	LS-705 Specific Gravity	Rating
120	10.0	10.0	10	**100**
138	9.6	9.3	10	**96**
139	8.0	5.0	9	**73**
146	10.0	10.0	10	**100**
171	4.6	8.7	10	**76**
172	9.8	9.0	9	**93**
188	8.0	10.0	10	**93**
208	9.2	10.0	10	**97**
210	7.0	9.0	10	**87**
216	10.0	9.3	8	**91**
253	8.6	8.7	5	**74**
260	8.2	9.7	4	**73**
284	9.4	9.0	10	**95**
285	9.0	9.0	10	**93**
296	9.6	7.0	10	**89**
299	8.4	7.0	10	**85**
300	4.4	10.0	10	**81**
301	9.4	7.7	9	**87**
i5	8.0	5.3	6	**64**

Appendix E4: Superpave Laboratory Ratings

Laboratory No.	C1252/T 304 Uncompacted Void Content	D2419/T 176 Sand Equivalent	ASTM D5821 % Fractured Particles	ASTM D4719 % Flat & Elongated	Rating
13	9	7	10	10	**90**
15	10	7	10	10	**93**
18	10	10	5	9	**85**
19	9	9	10	10	**95**
22	9	10	10	9	**95**
25	10	6	5	10	**78**
26	0	10	8	9	**68**
27	2	10	6	0	**45**
28	5	10	10	9	**85**
31	0	10	9	10	**73**
33	9	10	10	5	**85**
35	10	10	10	10	**100**
37	7	10	6	10	**83**
39	10	8	7	10	**88**
43	9	5	9	7	**75**
47	10	10	3	10	**83**
56	10	7	9	9	**88**
58	10	7	9	10	**90**
59	9	9	10	9	**93**
61	10	9	10	7	**90**
69	8	10	9	10	**93**
71	8	10	10	9	**93**
79	9	10	10	9	**95**
80	0	10	9	9	**70**
83	10	6	10	9	**88**
86	9	10	10	9	**95**
112	10	7	8	9	**85**
115	2	9	10	10	**78**
120	10	10	8	4	**80**
124	8	7	7	7	**73**
157	9	8	10	7	**85**
172	10	7	10	8	**88**
181	9	4	10	7	**75**
182	9	7	9	10	**88**
188	7	8	10	9	**85**
199	10	10	10	6	**90**

Laboratory No.	C1252/T 304 Uncompacted Void Content	D2419/T 176 Sand Equivalent	ASTM D5821 % Fractured Particles	ASTM D4719 % Flat & Elongated	Rating
215	6	8	10	9	**83**
216	10	10	10	9	**98**
235	10	10	0	9	**73**
236	7	10	7	10	**85**
245	10	10	8	8	**90**
255	10	8	9	8	**88**
263	9	10	9	9	**93**
271	10	10	6	9	**88**
273	10	10	10	10	**100**
285	10	10	8	10	**95**
293	10	10	10	9	**98**
294	6	10	10	8	**85**
295	10	9	10	10	**98**
296	10	10	10	10	**100**
316	7	10	8	7	**80**
325	10	10	10	9	**98**
326	10	10	10	10	**100**
327	0	9	10	10	**73**
328	10	10	10	9	**98**
340	10	10	9	10	**98**